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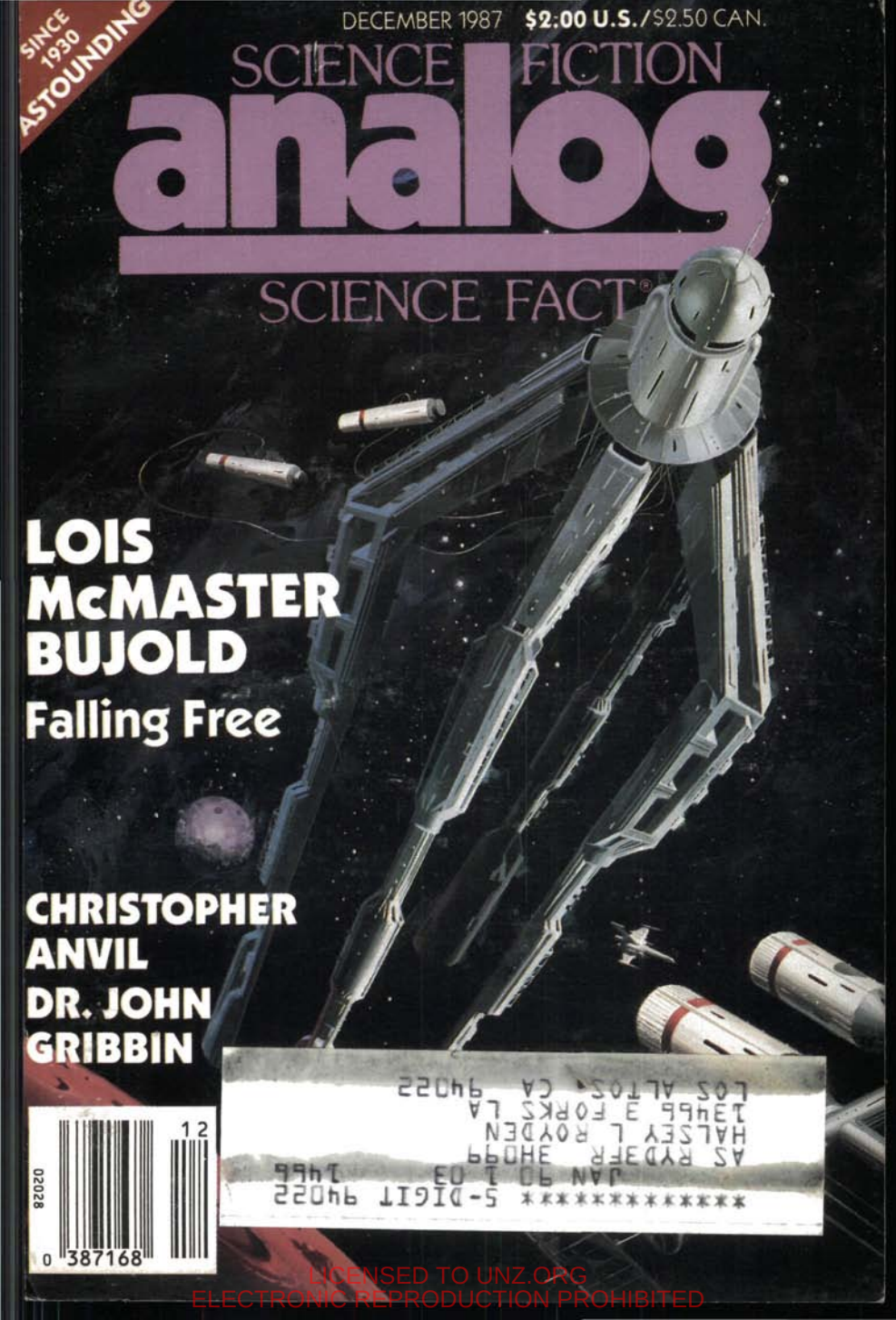

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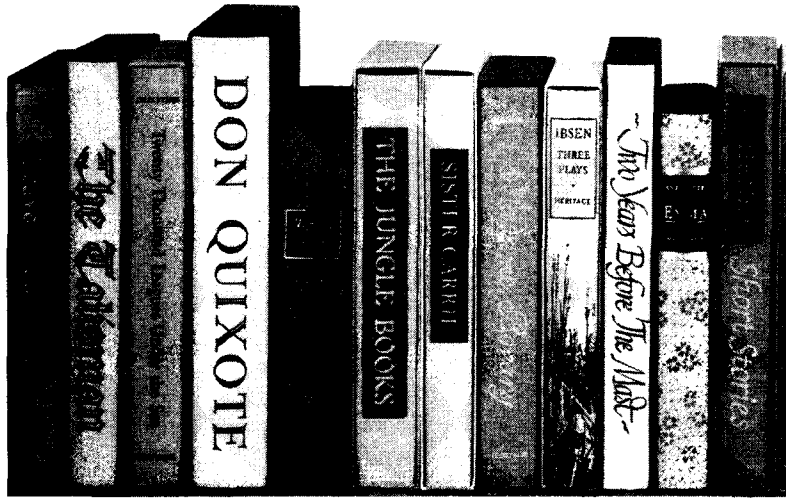

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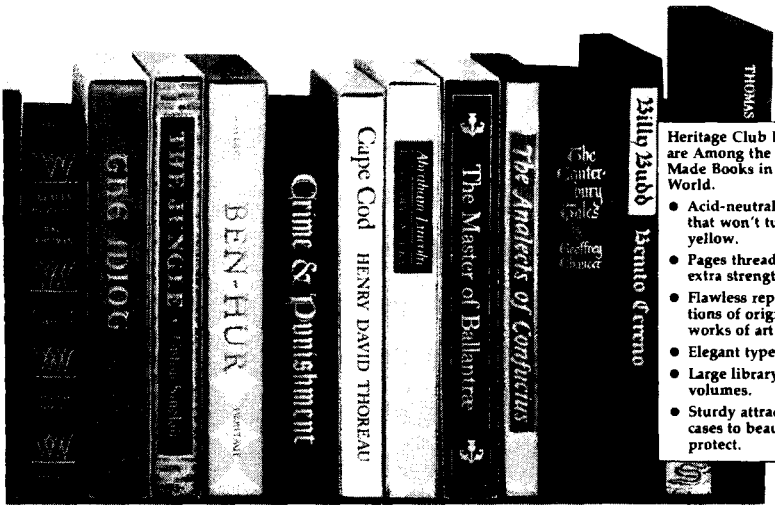

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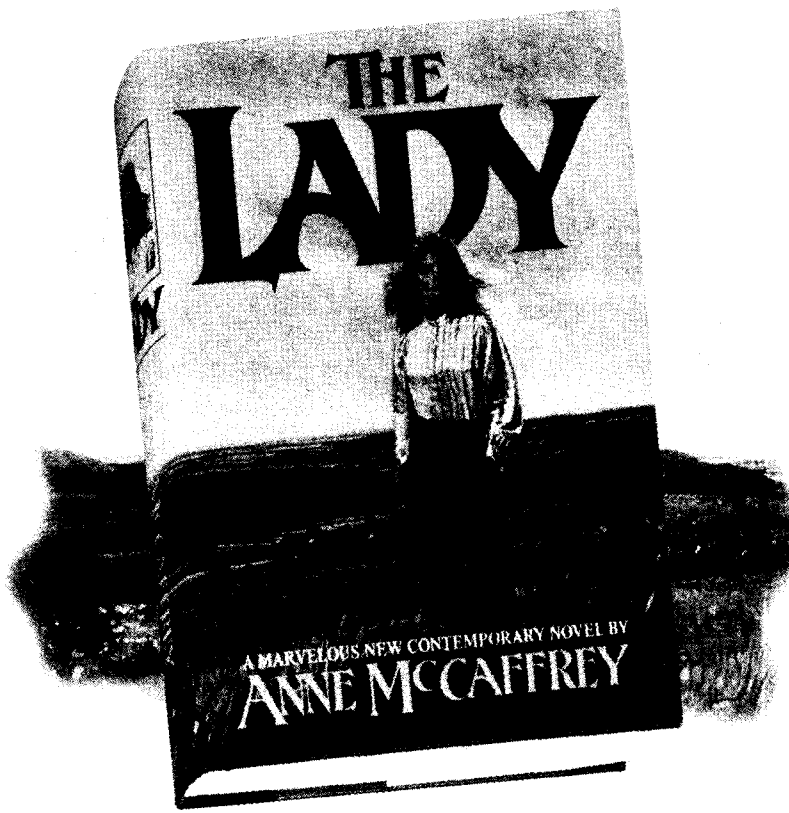

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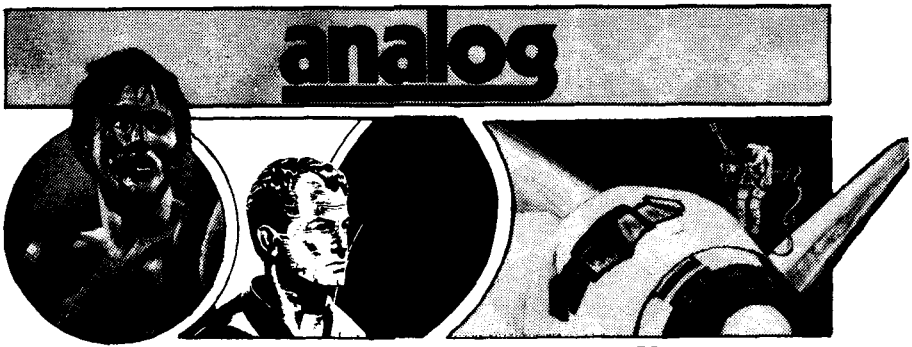

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Editorial

POLITICAL STANDARD TIME

Stanley Schmidt

My local newspaper carries a daily "Skywatch" column, by Dr. William Gutsch of New York's Hayden Planetarium, devoted to brief popular explanations of astronomical and meteorological phenomena, often dealing specifically with things happening in the sky on the date of publication. One of these was devoted to the astronomically peculiar status of the Islam holy month of Ramadan. The beginning of Ramadan, like a good many other religious occasions, is marked by an astronomical event—almost. Actually, perhaps because the founder wanted a clear visual sign that everybody could agree on, Ramadan begins with the first *sighting* of the crescent moon after a particular new moon. What's peculiar about that is that when the crescent moon becomes visible varies from one part of the world to another. Completely aside from atmospheric conditions (which were not often a problem in the deserts of the Middle East, and I'm not sure how Moslem authorities deal with them), the moon undergoes enough apparent motion during one rotation of the Earth that Ramadan as defined above may actually begin on different dates in different parts of the world. When Islam was young and most of its followers lived in a small region, such confusion was unlikely. The fact that it is possible now is a direct result of people's spreading out over much more of this planet than their ancestors ever foresaw. The fact that Moslems in different places can be aware of the confusion is a result of

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technologies that now allow rapid communication and travel between widely separated parts of the globe. (One might wonder in passing how the problem will be handled if and when Moslems colonize *other* globes, with many moons or none.)

Relatively few people in this country observe Ramadan, but practically all of us are more or less regularly involved with other rituals which, whether religious or secular, run headlong into the fact that the astronomical signposts by which we divide our lives into temporal compartments do not occur at the same time all over the planet. The most obvious examples are sunrise and sunset, which correspond very approximately with most people's boundaries between "work time" and "sleep time." When all phone calls were local, this was seldom a very serious problem, since most people have agreed to be diurnal and anyone with a clock could easily see whether it was a reasonable time to call someone. Now that technology allows practically instantaneous communication all over the globe, a simple look at the clock is no longer enough. A New Yorker who decides to call a friend in London at 9 P.M. had better have a very good reason for waking him at 2 A.M. Books have been written about how to cope with "jet lag," the physiological confusion caused by jumping from one time zone to another without allowing time for the body to make a gradual adjustment.

Having to deal with interactions between people living on significantly different times is a relatively new thing, brought about by technological advances that enable people to move much faster than a walk and to talk without getting physically close. Since all these things are pretty recent, maybe it's not too surprising that people are still groping a bit awkwardly for the best ways to deal with them. One particularly interesting dilemma that surfaces from time to time concerns the effect of all this rapid communication on politics. One of the central elements of the U.S. political process is the popular election, where on a designated day citizens all over the country go to local polling places to vote on candidates and issues, some of which are national and therefore affect people in all states. Typically, polls are open from something like 6 A.M. to 9 P.M. to allow people to go before or after work. This means that voters on the East Coast begin voting three hours earlier than those along the Pacific—and finish while their West Coast counterparts still have three hours to go. What bothers some people about this is that votes are counted quite rapidly these days, and the results are broadcast electronically as soon as they are available—and there is strong evidence that many people's decisions and actions are easily influenced in their choices by those of others. Thus evening voters in the West may be influenced in their choices by vote counts they've already heard from the East—and there may be enough of them to change the outcome of some national elections. Since an election is intended to provide a consensus of the voters' independent judgments, and not just reflect their at-

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tempts to ride or resist a trend, many people would like to do something to eliminate this kind of influence.

The same paper in which I saw the column about Ramadan had earlier carried a small news item about a proposal currently being considered by the U.S. House of Representatives. (It's remotely conceivable that some action will have been taken on it by the time you read this. The House passed a similar bill once before, but failed to get it past the Senate.) The essence of this proposal is that it would require all polling places in the 48 contiguous states to close at 9 P.M.—Eastern Standard Time.

That's all the information I have about it, but it certainly is an interesting approach to the problem. Let's see,

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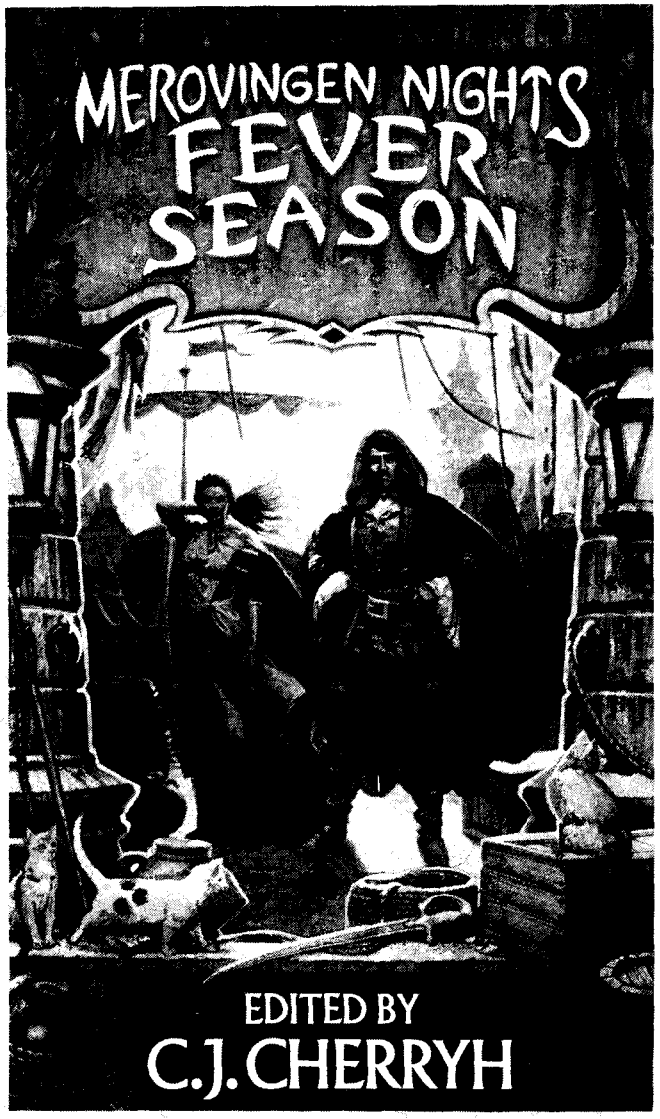

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now . . . does that mean Easterners get three more hours of voting time than Westerners? Or do Californians and Washingtonians get the option of getting up at 3 A.M. to make things "equal"? Do you think anybody in Oregon will actually consider that a satisfactory trade-off? (OK, OK—of course *somebody* will. You can find *somebody* to agree with *anything!*) A large percentage of the people I know find the evening by far the most convenient time to go to the polls. When some of them find the door slammed in their faces at 6 P.M. because they live on the West Coast, how many will bother to get up extra early to go to the polls at the crack of dawn? (And do you really want to be governed by people who are still half asleep?) Would the result be a disproportionate reduction in the number of voters actually voting in western states? New Yorkers might find this desirable, but I find it hard to believe that many Westerners would.

There *has* to be more to this than I've been told. So far it's been an amusing exercise, trying to imagine how the proponents of this scheme think they can make it genuinely equitable and palatable to voters everywhere, but it hasn't been easy to come up with anything believable.

Actually, the idea of having all election districts running on synchronized clocks would be a simple, elegant solution to the problem—*if* all times of day were created equal. It would make excellent sense in O'Neill colonies in space: since such artificial habitats have no natural day and night cycles, it would be perfectly practical, and in many ways advantageous, for them all to synchronize their artificial "days."

But *planets* aren't built that way, and political proposals to pretend they are seem oddly naive (or imaginative, depending on how you look at them). As long as planets rotate, sunrise and sunset are going to come sooner to some places than to others; and so are all the other reference times like "dinnertime" and "bedtime" that people are in the habit of relating to them. To a typical Oregonian or Washingtonian in the foreseeable future, 6 A.M. to 9 P.M. Pacific Time is going to seem a lot more equivalent to 6 A.M. to 9 P.M. Eastern Time than to any kind of 3 A.M. to 6 P.M.

So why are legislators in their wisdom going about it this way, when there's a much more straightforward solution? If the polls operate 6 A.M. to 9 P.M. *local* time, everywhere, the populations of all states should be equally satisfied with the range of voting times available to them. How to avoid East Coast returns influencing late West Coast voters? Very simple: don't allow any results to be broadcast until the last polls have closed in the West!

Yes, I know that Easterners would then have to either stay up late or wait until next morning to hear the results —but then, the early returns they're getting now aren't *final* results anyway. And if it's true that those early returns are now having an undue influence on final results, might not making the election as *meaningful* as possible be more important than making sure Philadelphians and Bostonians can hear the re-

(continued on page 121)

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Lois McMaster Bujold

FALLING FREE

Part I of IV

For working in an environment humans weren't evolved for, it might seem desirable to help evolution along. But that raises thorny questions about who's personnel and who's "equipment"

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CHAPTER ONE

The shining rim of the planet Rodeo wheeled dizzily past the observation port of the orbital transfer station. A woman whom Leo Graf recognized as one of his fellow disembarking passengers from the Jump ship stared eagerly out for a few minutes, then turned away, blinking and swallowing, to sit rather abruptly on one of the bright cushioned lounge chairs. Her eyes closed, opened, caught Leo's; she shrugged in embarrassment. Leo smiled sympathetically. Immune himself to the assorted nauseas of space travel, he moved to take her place at the crystal viewport.

Scanty cloud cover swirled in the thin atmosphere far below, barely veiling what seemed excessive quantities of red desert sand. Rodeo was a marginal world, home only to GalacTech mining and drilling operations and their support facilities. But what was he doing here? Leo wondered anew. Underground operations were hardly his field of expertise.

The planet slid from view with the rotation of the station. Leo moved to another port for a view back toward the hub of the station's wheel, noting the stress points and wondering when they'd last been x-rayed for secretly propagating flaws. Centrifugal *g*-forces here at the rim where this passenger lounge was situated seemed to be running at about half Earth-standard, a little light perhaps. Deliberately stress-reduced, trouble anticipated in the structure?

But he was here for training, they'd said at GalacTech headquarters on Earth, to teach quality control procedures in free-fall welding and construction. To whom? Why here, at the end of nowhere? "The Cay Project" was a singularly uninformative title for his assignment.

"Leo Graf?"

Leo turned. "Yes?"

The speaker was tall and dark-haired, perhaps thirty, perhaps forty. He wore conservative-fashionable civilian clothes, but a quiet lapel pin marked him as a company man. Best sedentary executive type, Leo decided. The hand he held out for Leo to shake was evenly tanned but soft. "I'm Bruce Van Atta."

Leo's thick hand was pale but flecked with brown spots. Crowding forty, sandy and square, Leo wore comfortable red company coveralls by long habit, partly to blend with the workers he supervised, mostly that he need never waste time and thought deciding what to put on in the morning. "Graf," read the label printed over his left breast pocket, eliminating all mystery.

"Welcome to Rodeo, the armpit of the universe," grinned Van Atta.

"Thank you," Leo smiled back automatically.

"I'm head of the Cay Project now; I'll be your boss," Van Atta amplified. "I requested you personally, y'know. You're going to help me get this division moving at last, jack it up and light a fire under it. You're like me, I know, got no patience with deadheads. It was a hell of a job to have dumped on me, trying to make *this* division profitable—but if I succeed, I'll be the Golden Boy."

"Requested me?" Cheering, to think that his reputation preceded him, but why couldn't one ever be Requested by somebody at a garden spot? Ah, well . . .

"They told me at HQ that I was being

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sent out here to give an expanded version of my short course in nondestructive testing."

"Is that all they told you?" Van Atta asked in astonishment. At Leo's affirmative shrug, he threw back his head and laughed. "Security, I suppose," Van Atta went on when he'd stopped chuckling. "Are you in for a surprise. Well, well. I won't spoil it." Van Atta's sly grin was as irritating as a familiar poke in the ribs.

Too familiar—oh, hell, Leo thought, this guy *knows* me from somewhere. And he thinks I know him. . . . Leo's polite smile became fixed in mild panic. He had met thousands of GalacTech personnel in his eighteen-year career. Perhaps Van Atta would say something soon to narrow the possibilities.

"My instructions listed a Dr. Cay as titular head of the Cay Project," Leo probed. "Will I be meeting him?"

"Old data," said Van Atta. "Dr. Cay died last year—several years past the date he should have been forcibly retired, in my opinion, but he was a vice president and major stockholder and thoroughly entrenched—but that's blood over the damned dam, eh? I replaced him." Van Atta shook his head. "But I can't wait to see the look on your face when you see—come along. I have a private shuttle waiting."

They had the six-man personnel shuttle to themselves, but for the pilot. The passenger seat molded itself to Leo's body during the brief periods of acceleration. Quite brief periods; clearly they were not braking for planetary reentry. Rodeo turned beneath them, falling farther away.

"Where are we going?" Leo asked Van Atta, seated beside him.

"Ah," said Van Atta. "See that speck about thirty degrees above the horizon? Watch it. It's home base for the Cay Project."

The speck grew rapidly into a far-flung chaotic structure, all angles and projections, with confetti-colored lights spangling its sharp shadows. Leo's practiced eye picked out the clues to its function, the tanks, the ports, the greenhouse filters winking in the sunlight, the size of the solar panels versus the estimated volume of the structure.

"An orbital habitat?"

"You got it," said Van Atta.

"It's huge."

"Indeed. How many personnel would you guess it could handle?"

"Oh—fifteen hundred."

Van Atta's eyebrows rose, in slight disappointment, perhaps, at not being able to offer a correction. "Almost exactly. Four hundred-ninety-four rotating GalacTech personnel and a thousand permanent inhabitants."

Leo's lips echoed the word, permanent. . . . "Speaking of rotation—how are you handling null-*g* deconditioning in your people? I don't—" his eyes inventoried the enormous structure, "I don't even see an exercise wheel. No spinning gym?"

"There's a null-*g* gym. The rotating personnel get a month downside after every three-month shift."

"Expensive."

"But we put the Habitat up there for less than a quarter of the cost of the same volume of living quarters in one-*g* spinners."

"But surely you'll lose what you've

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saved in construction costs over time in personnel transportation and medical expenses,'' argued Leo. ''The extra shuttle trips, the long leaves—every retiree who breaks an arm or a leg until the day he dies will be suing GalacTech for the cost of it plus mental anguish, whether he had significant bone demineralization or not.''

''We've solved that problem too,'' said Van Atta. ''Whether the solution is cost-effective—well, that's what you and I are here to try and prove.''

The shuttle sidled delicately into alignment with a hatch on the side of the Habitat and seated itself with a reassuringly authoritative click. The pilot shut down his systems and unbuckled himself to float past Leo and Van Atta and check the hatch seals. ''Ready for disembarking, Mr. Van Atta.''

''Thank you, Grant.''

Leo released his seat restraints, and stretched and relaxed in the pleasurable familiarity of weightlessness. Not for him the unfortunate nauseas of null-*g* that sapped the efficiency of so many employees. Leo's body was ordinary enough, downside; here, where control and practice and wit counted more than strength, he was at last an athlete. Smiling a little to himself, he followed Van Atta from hand-grip to hand-grip and through the shuttle hatch.

A pink-faced tech manned a control panel just inside the shuttle hatch corridor. He wore a red T-shirt with the GalacTech logo over his left breast. Tight blond curls cut close to his head reminded Leo of a lamb's pelt; perhaps it was an effect of his obvious youth.

''Hello there, Tony,'' Van Atta greeted him with cheerful familiarity.

''Good afternoon, Mr. Van Atta,'' the youth replied deferentially. He smiled at Leo, and cocked his head at Van Atta in a pantomime plea for an introduction. ''Is this the new teacher you were telling us about?''

''Indeed he is. Leo Graf, this is Tony—he'll be among your first trainees. He's one of the habitat's *permanent* residents,'' Van Atta added with peculiar emphasis. ''Tony is a welder and joiner, second grade—working on first, eh, Tony? Shake hands with Mr. Graf.''

Van Atta was smirking. Leo had the impression that if he hadn't been in free fall, he would have been bouncing on his heels.

Tony pulled himself obediently over the control panel. He wore red shorts—

Leo blinked, and caught his breath in shock. The boy had no legs. Emerging from his shorts was a second set of arms.

Functional arms, he was even now using his—his lower left hand, Leo supposed he'd have to call it—to anchor himself as he reached out to Leo. His smile was perfectly unselfconscious.

Leo had lost his own hand grip, and had to fumble to retrieve it, and stretch awkwardly to meet the proffered handshake. ''How do you do,'' Leo managed to croak. It was almost impossible not to stare. Leo forced his gaze to focus on the young man's bright blue eyes.

''Hello, sir. I've been looking forward to meeting you.'' Tony's handshake was shy but sincere, his hand dry and strong.

''Um . . .'' Leo stumbled, ''Um, what's your last name, uh, Tony?''

''Oh, Tony's just my nickname, sir.

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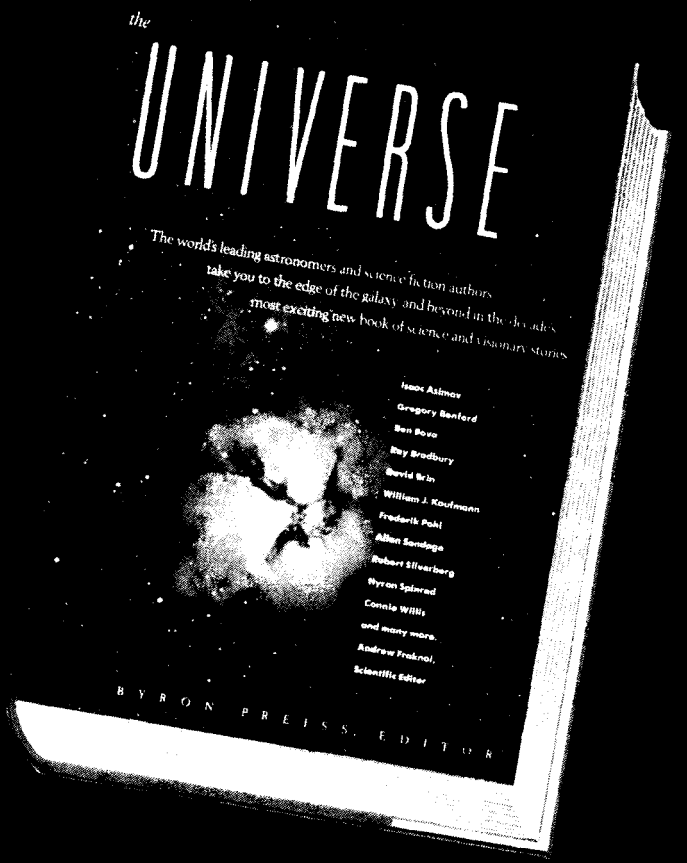

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"I, uh—guess I'll call you Tony, then," Leo murmured, increasingly stunned. Van Atta, most unhelpfully, seemed to be thoroughly enjoying Leo's discomfirture.

"Everybody does," said Tony agreeably.

"Fetch Mr. Graf's bag, will you, Tony?" said Van Atta. "Come on, Leo, I'll show you your quarters, and then we can do the grand tour."

Leo followed his floating guide into the indicated cross-corridor, glancing back over his shoulder in renewed amazement as Tony launched himself accurately across the chamber and swung through the shuttle hatch.

"That's," Leo swallowed, "that's the most extraordinary birth defect I've ever seen. Somebody had a stroke of genius, to find him a job in free fall. He'd be a cripple, downside."

"Birth defect." Van Atta's grin had grown twisted. "Yeah, that's one way of describing it. I wish you could have seen the look on your own face, when he popped up like that. I congratulate you on your self-control. I about puked when I first saw one, and I was prepared. You get used to the little chimps pretty quick, though."

"There's more than one?"

Van Atta opened and closed his hands in a counting gesture. "An even one thousand. The first generation of GalacTech's new super-workers. The name of the game, Leo, is bioengineering. And I intend to win."

Tony, with Leo's valise clutched in his lower right hand, swooped between Leo and Van Atta in the cylindrical corridor and braked to a halt in front of them with three deft touches on the passing hand-grips.

"Mr. Van Atta, can I introduce Mr. Graf to somebody on the way to Visitor's Wing? It won't be *much* out of the way—Hydroponics."

Van Atta's lips pursed, then arranged themselves in a kindly smile. "Why not? Hydroponics is on the itinerary for this afternoon anyway."

"Thank you, sir," cried Tony, and darted off with enthusiasm to open the air safety seal before them at the end of the corridor, and linger to close it again behind them on the other side.

Leo fastened his attention on his surroundings, as a less-rude alternative to surreptitious study of the boy. The Habitat was indeed inexpensively constructed, mostly pre-fab units variously combined. Not the most aesthetically elegant design—a certain higgledy-piggledy randomness indicated an organic growth pattern since the Habitat's inception, units stuck on here and there to accommodate new needs. But its very dullness incorporated safety advantages Leo approved, the interchangeability of airseal systems for example.

They passed dormitory wings, food preparation and dining areas, a workshop for small repairs—Leo paused to gaze down its length, and had to hurry to catch up with his guide. Unlike most free-fall living spaces Leo had worked in, there was no effort here to maintain an arbitrary up-and-down to ease the visual psychology of the inhabitants. Most chambers were cylindrical in design, with work spaces and storage efficiently packing the walls and the center left free of obstruction for the

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passage of—well, one could hardly call them pedestrians.

En route they passed a couple of dozen of the—the four-handed people, the new model workers, Tony's folk, whatever they were called—did they have an official designation, Leo wondered? He stared covertly, breaking off his gaze whenever one looked back, which was often; they stared openly at him, and whispered among themselves.

He could see why Van Atta dubbed them chimps. They were thin-hipped, lacking the powerful gluteal locomotor muscles of people with legs. The lower set of arms tended to be more muscular than the uppers in both males and females, power-grippers, and thus appeared falsely short by comparison to the uppers; bow-legged, if he squinted them to a blur.

They were dressed mostly in the sort of comfortable, practical T-shirt and shorts that Tony wore, evidently color-coded, for Leo passed a cluster of them all in yellow hovering intently around a normal human in GalacTech coveralls who had a pump unit half-apart, lecturing on its function and repair. Leo thought of a flock of canaries, of flying squirrels, of monkeys, of spiders, of swift bright lizards of the sort that run straight up walls.

They made him want to scream, almost to weep; and yet it wasn't the arms, or the quick, too-many hands. He had almost reached Hydroponics before he was able to analyze his intense unease. It was their faces that bothered him so, Leo realized. They were the faces of children . . .

A door marked "Hydroponics D" slid aside to reveal an antechamber and a large airy end chamber extending some fifteen meters beyond. Filtered windows on the sun side, and an array of mirrors on the dark side, filled the volume with brilliant light, softened by green plants that grew from a carefully-arranged set of grow tubes. The air was pungent with chemicals and vegetation.

A pair of the four-armed young women, both in blue, were at work in the antechamber. A plexiplastic grow tube three meters long was braced in place, and they floated along its length carefully transplanting tiny seedlings from a germination box into a spiral series of holes along the tube, one plant per hole, fixing them in place with flexible sealant around each tender stalk. The roots would grow inward, becoming a tangled mat to absorb the nutritive hydroponic mists pumped through the tube, and the leaves and stems would bush out in the sunlight and eventually bear whatever fruit was their genetic destiny. In this place, probably apples with antlers, thought Leo in mild hysteria, or potatoes with eyes that really winked at you.

The dark-haired girl paused to adjust a bundle under her arm. . . . Leo's mind ground to a complete halt. The bundle was a baby.

A live baby—of course it was alive, what did he expect? Leo gibbered inwardly. It peered around its—mother's—torso to glower suspiciously at Leo-the-stranger, and tightened its four-handed clutch on home base, taking a squishy defensive grip on one of the girl's breasts as if in fear of competition. "Ackle," it remarked aggressively.

"Ow!" The dark-haired girl laughed, and spared a lower hand to pry the little

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fat fingers loose without missing a beat of her upper hands patting sealant in place around a stem. She finished with a quick squirt of fixative from a tube floating conveniently beside her, just out of the infant's reach.

The girl was slim, and elvish, and wonderfully weird to Leo's unaccustomed eyes. Her short, fine hair clung close to her head, framing her face, shaped to a point at the nape of her neck. It was so thick it reminded Leo of cat fur; one might stroke it, and be soothed.

The other girl was blonde, and babyless. She looked up first, and smiled, "Company, Claire."

The dark-haired girl's face lit with pleasure. Leo flushed in the heat of it. "Tony!" she cried happily, and Leo realized he had merely received an accidental dose, as it were, of that beam of delight, as it swept over him to its true target.

The baby released three hands and waved them urgently. "Ah, ah!" The girl turned in air to face the visitors. "Ah, ah, *aha!*" the baby repeated.

"Oh, all *right,*" she laughed. "You want to fly to Daddy, hm?" She unhooked a short tether from a sort of soft harness on the baby's torso to a belt around her own waist, and held the infant out. "Fly to Daddy, Andy? Fly to Daddy?"

The baby indicated enthusiasm for the proposal by waving all four hands vigorously about and squealing eagerly. She launched him toward Tony with considerably more velocity than Leo would have dared to impart. Tony, grinning cheerfully, caught him—handily, Leo thought in blitzed inanity.

"Fly to Mommy?" Tony inquired in turn. "Ah, ah," the baby agreed, and Tony hung him in air, gently pulling his arms out—like straightening out a starfish, Leo thought—and imparting a spin rolled him through the air for all the world like a wheel. The baby pulled his hands in, clenching his face in sympathetic effort, and spun faster, and gurgled with laughter at the success of his effort. Conservation of angular momentum, thought Leo. Naturally . . .

Claire tossed the infant back one more time to his father—mind-boggling, to think of that blond boy as a father of anything—and followed herself to brake to a halt hand-to-hand against Tony, who proffered an automatic helping grasp for that purpose. That they continued to hold hands was clearly more than a courteous anchoring.

"Claire, this is Mr. Graf," Tony did not so much introduce as display him, like a prize. "He's going to be my advanced welding techniques teacher. Mr. Graf, this is Claire, and this is our son Andy." Andy had clambered headward on his father, and was wrapping one hand in Tony's blond hair and another around one ear, blinking owlishly at Leo. Tony gently rescued the ear and redirected the clutch to the fabric of his red T-shirt. "Claire was picked to be the very first natural mother of us," Tony went on proudly.

"Me and four other girls," Claire corrected modestly.

"Claire used to be in Welding and Joining too, but she can't do Outside work any more," Tony explained. "She's been in Housekeeping, Nutrition Technology, and Hydroponics since Andy was born."

"Dr. Yei said I was a very important

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experiment, to see which sorts of productivity were least compromised by my taking care of Andy at the same time," explained Claire. "I sort of miss going Outside—it was exciting—but I like this, too. More variety."

GalacTech reinvents Women's Work? thought Leo bemusedly. Are we about to put an R&D group to work on the applications of fire, too? But oh, you are certainly an experiment. . . . His thought was unreflected in his bland, closed face. "Happy to meet you, Claire," he said gravely.

Claire nudged Tony, and nodded toward her blonde coworker, who had drifted over to join the group.

"Oh—and this is Silver," Tony went on obediently. "She works in Hydroponics most of the time."

Silver nodded. Her medium-short hair drifted in soft platinum waves, and Leo wondered if it was the source of her nickname. She had the sort of strong facial bones that are sharp and unhappily awkward at thirteen, arrestingly elegant at thirty-five, now not quite halfway through their transition. Her blue gaze was cooler and less shy than the busy Claire's, who was already distracted by some new demand from Andy. Claire retrieved the baby and reattached his safety line.

"Good afternoon, Mr. Van Atta," Silver added particularly. She pirouetted in air, with eyes that cried silently, Notice me! Leo noticed that all twenty of her manicured fingernails were lacquered pink.

Van Atta's answering smile was secretive and smug. "Afternoon, Silver. How's it going?"

"We have one more tube to plant after this one. We'll be finished ahead of shift change," Silver offered.

"Fine, fine," said Van Atta jovially. "Ah—do try to remember to arrange yourself right-side up when you're talking to a downsider, Sugarplum."

Silver inverted herself hastily to match Van Atta's orientation. Since the room was radially arranged, right-side-up was a purely Van Atta-centric direction. Leo noted dryly. Where *had* he met the man before?

"Well, carry on, girls." Van Atta led the way out, Leo following, Tony bringing up the rear regretfully, looking back over his shoulder.

Andy had returned his attention to his mother, his determined little hands foraging up her shirt, on which dark stains were spreading in autonomic response. Apparently that was one bit of ancient biology the company had not altered. The milk dispensers were certainly ideally preadapted to life in free fall, after all. And even diapers had a heroic history in the dawn of space travel, Leo had heard.

His brief amusement drained away, and he pushed off after Van Atta, silent and reflective. He held his judgement suspended, he reassured himself, not paralyzed. In the meantime, a closed mouth could not impede the inflow of data.

They paused at Van Atta's Habitat office. Van Atta switched on the lights and air circulation as they entered. From the stale smell Leo guessed the office was not often used; the executive probably spent most of his time more comfortably downside. A large viewport framed a spectacular view of Rodeo.

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"I've come up in the world a bit since we last met," said Van Atta, matching his gaze. The upper atmosphere along Rodeo's rim was producing some gorgeous prismatic light effects at this angle of view. "In several senses. I don't mind returning the favor. The man at the top owes it to remember how he got there, I think. Noblesse oblige and all that." The tilt of Van Atta's eyebrow invited Leo to join him in self-congratulatory satisfaction.

Remember. Quite. Leo's blank memory was getting excruciatingly uncomfortable. He smiled and seized the pause while Van Atta activated his desk comconsole to turn away and make a slow, politely-waiting-type orbit of the room, as if idly examining its contents.

A little wall plaque bearing a humorous motto caught his eye. *On the sixth day God saw He couldn't do it all,* it read, *so He created ENGINEERS.* Leo snorted, mildly amused.

"I like that too," commented Van Atta, looking up to check the cause of his chuckle. "My ex-wife gave it to me. It was about the only thing the greedy bitch didn't take back when we split."

"Were you an—" Leo began, and swallowed the words, *engineer, then?* as he finally remembered, and then wondered how he could ever have forgotten. Leo had known Van Atta as an engineering subordinate at that time, though, not as an executive superior. Was this sleek go-getter the same idiot he had kicked impatiently upstairs to Administration just to get him out from underfoot on the Morita Station project—ten, twelve years ago now? Brucie-baby. Oh, yes. Oh, hell . . .

Van Atta's comconsole disgorged a couple of data disks, which he plucked off. "You put me on the fast track. I've always thought it must give you a sense of satisfaction, since you spend so much of your time training, to see one of your old students make good."

Van Atta was no more than five years younger than Leo. Leo suppressed profound irritation—he wasn't this paper-shuffler's ninety-year-old retired Sunday school teacher, damn it. He was a working engineer, hands-on, and not afraid to get them dirty, either. His technical work was as close to perfection as his relentless conscientiousness could push it, his safety record spoke for itself. . . . He let his anger go with a sigh. Wasn't it always so? He'd seen dozens of subordinates forge ahead, often men he'd trained himself. Yeah, and trust Van Atta to make it seem a weakness and not a point of pride.

Van Atta spun the data disks across the room at him. "There's your roster and your syllabus. Come on, and I'll show you some of the equipment you'll be working with. GalacTech's got two projects in the wind they're thinking of finally turning these Cay Project quaddies loose on."

"Quaddies?"

"The official nickname."

"It's not, um . . . pejorative?"

Van Atta stared, then snorted. "No. What you do not call them out loud, however, is 'mutants,' genetic paranoia being what it is after that Nuovo Brasilian military cloning fiasco. This whole project could have been carried out much more conveniently in Earth orbit, but for the assorted legal hysterias about human gene manipulation. Anyway, the projects. One to assemble Jump ships

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in orbit around Orient IV, and another building a deep space transfer facility at some nexus away the hell-and-gone beyond Tau Ceti called Kline Station —cold work, no habitable planets in the system and its sun is a cinder, but the local space harbors no less than six wormhole exits. Potentially very profitable. Lots of welding under the most difficult free-fall conditions—''

Leo's brief angst was swallowed in interest. It had always been the work itself, not the pay and perks, that held him in thrall. Screw executive privilege—didn't it mostly mean being stuck downside? He followed Van Atta out of the office back into the corridor where Tony still waited patiently with his luggage.

''I suppose it was the development of the uterine replicators that made it all possible,'' Van Atta opined while Leo stowed his gear in his new quarters. More than a mere sleep cubicle, the chamber included private sanitary facilities and a comconsole as well as comfortable-looking sleeping restraints—no morning backache on this job, Leo thought with minor satisfaction. Headache was another problem.

''I'd heard something about those things,'' said Leo. ''Another invention from Beta Colony, wasn't it?''

Van Atta nodded. ''The outer worlds are getting too damn clever these days. Earth's going to lose its edge if it doesn't shape up.''

Too true, Leo thought. Yet the history of innovation suggested this was an inevitable pattern. Management who had made huge capital investments in one system were naturally loathe to scrap it, and so the latecomers forged ahead—to the frustration of loyal engineers. . . . ''I'd thought the use of uterine replicators was limited to obstetrical emergencies.''

''Actually, the only limitation on their use is the fact that they're hideously expensive,'' said Van Atta. ''It's probably only a matter of time before rich women everywhere start ducking their biological duties and cooking up their kids in 'em. But for GalacTech, it meant that human bioengineering experiments could at last be carried out without involving a lot of flaky fostermothers to carry the implanted embryos. A neat, clean, controlled engineering approach. Better still, these quaddies are total constructs—that is, their genes are taken from so many sources, it's impossible to identify their genetic parents either. Saves quantities of legal grief.''

''I'll bet,'' said Leo faintly.

''This whole thing was Dr. Cay's obsession, I gather. I never met him, but he must have been one of those, you know, charismatic types, to push through a project with this enormous lead time before any possible pay-off. The first batch is just turning twenty. The extra arms are the wildest part—''

''I've often wished I had four hands, in free-fall,'' Leo murmured, trying not to sound too dubious out loud.

''—but most of the changes were this bunch of metabolic stuff. They never get motion-sick—something about rewiring the vestibular system—and their muscles maintain tone with an exercise regimn of barely fifteen minutes a day, max—nothing like the hours you and I would have to put in during a long stint

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in null-*g*. Their bones don't deteriorate at all. They're even more radiation-resistant than us. Bone marrow and gonads can take four and five times the rems we can absorb before GalacTech grounds us—although the medical types are pushing for them to do their reproducing early in life, while all those expensive genes are still pristine. After that, it's all gravy for us; workers who never require downside leave; so healthy they'll go on and on, cutting high-cost turnover; they're even,'' Van Atta snickered, ''self-replicating.''

Leo secured the last of his scanty personal possessions. ''Where . . . will they go when they, uh, retire?'' he asked slowly.

Van Atta shrugged. ''I suppose the company will have to work something out, when the time comes. Not my problem, fortunately; *I'll* be retired before then.''

''What happens if they—quit, go elsewhere? Suppose somebody offers them higher pay? GalacTech will be out-of-pocket for all that R&D.''

''Ah. I don't think you've quite grasped the beauty of this set-up. They don't quit. They aren't employees. They're capital equipment. They aren't paid in money—though I wish *my* salary was equal to what GalacTech is spending yearly to maintain 'em. But that will get better as the last replicator cohort gets older and more self-sufficient. They stopped producing new ones about five years ago, see, in anticipation of turning that job over to the quaddies themselves.'' Van Atta licked his lips and raised his eyebrows, as if in enjoyment of a salacious joke. Leo could not regret missing its point.

Leo turned, curling in air and crossing his arms. ''Spacer's Union is going to call it slave labor, you know,'' he said at last.

''The Union's going to call it worse names than that. Their productivity is going to look sick,'' growled Van Atta. ''Loaded language bullshit. These little chimps have cradle to grave security. GalacTech couldn't be treating them better if they were made of solid platinum. You and I should have so good a deal, Leo.''

''Ah,'' said Leo, and no more.

CHAPTER TWO

The observation bubble on the side of the Cay Habitat had a televiewer, Leo discovered to his delight, and furthermore it was unoccupied at the moment. His own quarters lacked a viewport. He slipped within. His schedule allowed this one free day, to recover from trip fatigue and Jump lag before his course was to begin. A good night's sleep in free fall had already improved his tone of mind vastly over yesterday, after Van Atta's—Leo could only dub it ''disorientation tour.''

The curve of Rodeo's horizon bisected the view from the bubble, and beyond it the vast sweep of stars. Just now one of Rodeo's little mouse moons crept across the panorama. A glint above the horizon caught Leo's eye.

He adjusted the televiewer for a close-up. A GalacTech shuttle was bringing up one of the giant cargo pods, refined petrochemicals or bulk plastics bound for petroleum-depleted Earth perhaps. A collection of similar pods floated in orbit. Leo counted. One, two, three . . . six, and the one arriving made

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seven. Two or three little manned pushers were already starting to bundle the pods, to be locked together and attached to one of the big orbit-breaking thruster units.

Once grouped and attached to their thruster, the pods would be aimed toward the distant wormhole exit point that gave access to Rodeo local space. Velocity and direction imparted, the thruster would detach and return to Rodeo orbit for the next load. The unmanned pod bundle would continue on its slow, cheap way to its target, one of a long train stretching from Rodeo to the anomaly in space that was the Jump point.

Once there, the cargo pods would be captured and decelerated by a similar thruster, and positioned for the Jump. Then the Superjumpers would take over, cargo carriers as specially designed as the thrusters for their task. The monster cargo jumpers were hardly more than a pair of Necklin field generator rods in their protective housings, so positioned as to be fitted around a constellation of pod bundles, a bracketing pair of normal space thruster arms, and a small control chamber for the Jump pilot and his neurological headset. Without their balancing pod bundles attached, the Superjumpers reminded Leo of some exceptionally weird and attenuated long-legged insects.

Each Jump pilot, neurologically wired to his ship to navigate the wavering realities of wormhole space, made two hops a day, inbound to Rodeo with empty pod bundles and back out again with cargo, followed by a day off; two months on duty followed by a month's unpaid but compulsory gravity leave, usually financially augmented with shuttle duties. Jumps were more wearing on pilots than null-*g* was. The pilots of the fast passenger ships like the one Leo had ridden in on yesterday called the Superjumper pilots puddle-jumpers and merry-go-round riders. The cargo pilots just called the passenger pilots snobs.

Leo grinned, and considered that train of wealth gliding through space. No doubt about it, the Cay Habitat, fascinating as it was, was just the tail of the dog to the whole of GalacTech's Rodeo operation. That single thruster-load of pods being bundled now could maintain a whole town full of stockholding widows and orphans in style for a year, and it was just one of an apparently endless string. Base production was like an inverted pyramid, those at the bottom apex supporting a broadening mountain of ten-percenters, a fact which usually gave Leo more secret pride than irritation.

"Mr. Graf?" an alto voice interrupted his thoughts. "I'm Dr. Sondra Yei. I head up the psychology and training department for the Cay Habitant."

The woman hovering in the door wore pale green company coveralls. Pleasantly ugly, pushing middle-age, she had the bright mongolian eyes, broad nose and lips and coffee-and-cream skin of her mixed racial heritage. She pushed herself through the aperture with the concise relaxed movements of one accustomed to free fall.

"Ah, yes, they told me you'd be wanting to talk to me." Leo courteously waited for her to anchor herself before attempting to shake hands.

Leo gestured at the televiewer. "Got

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a nice view of the orbital cargo marshalling here. Seems to me that might be another job for your quaddies."

"Indeed. They've been doing it for almost a year now." Yei smiled satisfaction. "So, you don't find adjusting to the quaddies too difficult? So your psyche profile suggested. Good."

"Oh, the quaddies are all right." Leo stopped short of expanding on his unease. He was not sure he could put it into words anyway. "I was just surprised, at first."

"Understandable. You don't think you'll have trouble teaching them, then?"

Leo smiled. "They can't possibly be worse than the crew of roustabouts I trained at Jupiter Orbital #4."

"I didn't mean trouble *from* them." Yei smiled again. "You will find they are very intelligent and attentive students. Quick. Quite literally, good children. And that's what I want to talk about." She paused, as if marshalling her thoughts like the distant cargo pushers.

"The GalacTech teachers and trainers occupy a parental role here for the Habitat family. Although parentless, the quaddies themselves must someday —indeed, are already becoming parents. From the beginning we've been at pains to assure they were provided with role models of stable responsibility. But they *are* still children. They will be watching you closely. I want you to be aware, and take care. They'll be learning more than welding from you. They'll also be picking up your other patterns of behavior. In short, if you have any bad habits—and we all have some—they must be parked downside for the duration of your stay. In other words," Yei went on, "watch yourself. Watch your language." An involuntary grin crinkled her eyes. "For example, one of our crèche personnel once used the cliché 'spit in your eye' in some context or other . . . not only did the quaddies think it was hilarious, but it started an epidemic of spitting among the five year olds that took weeks to suppress. Now, you'll be working with much older children, but the principle remains. For instance—ah—did you bring any personal reading or viewing matter with you? Vid dramas, newsdiscs, whatever."

"I'm not much of a reader," said Leo. "I brought my course material."

"Technical information doesn't concern me. What we've been having a problem with lately is, um, fiction."

Leo raised an eyebrow, and grinned. "Pornography? I'm not sure I'd worry about that. When I was a kid we passed around—"

"No, no, not pornography. I'm not sure the quaddies would understand about pornography anyway. Sexuality is an open topic here, part of their social training. Biology. I'm far more concerned about fiction that clothes false or dangerous values in attractive colors, or biased histories."

Leo wrinkled his forehead, increasingly dismayed. "Haven't you taught these kids any history? Or let them have stories . . . ?"

"Of course we have. The quaddies are well-supplied with both. It's simply a matter of correct emphasis. For example—a typical downsider history of, say, the settlement of Orient IV usually gives about fifteen pages to the year of the Brothers' War, a temporary if bi-

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zarre social aberration—and about two to the actual hundred or so years of settlement and building-up of the planet. Our text gives one paragraph to the war. But the building of the Witgow transtrench monorail tunnel, with its subsequent beneficial economic effects to both sides, gets five pages. In short, we emphasize the common instead of the rare, building rather than destruction, the normal at the expense of the abnormal. So that the quaddies may never get the idea that the abnormal is somehow expected of them. If you'd like to read the texts, I think you'll get the idea very quickly."

"I—yeah, I think I'd better," Leo murmured. The degree of censorship imposed upon the quaddies implied by Yei's brief description made his skin crawl—and yet, the idea of a text that devoted whole sections to great engineering works made him want to stand up and cheer. He contained his confusion in a bland smile. "I really didn't bring anything on board," he offered placatingly.

She led him off for a tour of the dormitories, and the supervised crèches of the younger quaddies.

The little ones amazed Leo. There seemed to be so many—maybe it was just because they moved so fast. Thirty or so five year olds bounced around the free-fall gym like a barrage of demented ping pong balls when their crèche mother, a plump pleasant downsider woman they called Mama Nilla, assisted by a couple of quaddie teenage girls, first let them out of their reading class. But then she clapped her hands, and put on some music, and they fell to and demonstrated a game, or a dance, Leo was not sure which, with many sidelong looks at him and much giggling. It involved creating a sort of duo-decahedron in mid-air, like a human pyramid only more complex, hand to hand to hand changing its formation in time to music. Cries of dismay went up when an individual slipped up and spoiled the group's formation. When perfection was achieved, everybody won. Leo couldn't help liking that game. Dr. Yei, watching Leo laugh when the young quaddies swarmed around him afterwards, seemed to purr with contentment.

But at the end of the tour she studied him with a little smile quirking her mouth. "Mr. Graf, you're still disturbed. You sure you're not harboring just a little of the old Frankenstein complex about all this? It's all right to admit it to me—in fact, I want you to talk about it."

"It's not that," said Leo slowly. "It's just . . . well, I can't really object to your trying to make them as group-centered as possible, given that they'll be living all their lives on crowded space stations. They're disciplined to a high degree for their ages, also good—"

"Vital to their survival, rather, in a space environment!"

"Yes . . . but what about—about their self-defense?"

"You'll have to define that term for me, Mr. Graf. Defense from what?"

"Well, it seems to me you've succeeded in raising about a thousand technical whiz—doormats. Nice kids, but aren't they a little—feminized?" He was getting in deeper and deeper; her smile had quirked to a frown. "I mean—they just seem ripe for exploitation by—by somebody. Was this whole

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social experiment your idea? It seems like a woman's dream of a perfect society. Everybody's so *well behaved*." He was uncomfortably conscious of having expressed his thought badly, but surely she must see the validity. . . .

She took a deep breath, and lowered her voice. Her smile had become fixed. "Let me set you straight, Mr. Graf. I did not invent the quaddies. I was assigned here six years ago. It's the GalacTech specs that call for *maximum socialization*. But I did inherit them. And I care about them. It's not your job—or your business—to understand about their legal status, but it concerns me greatly. Their safety lies in their socialization.

"You seem to be free of the common prejudices against the products of genetic engineering, but there are many who are not. There are planetary jurisdictions where this degree of genetic manipulation of humans would even be illegal. Let those people—just once—perceive the quaddies as a threat, and—" she clamped her lips on further confidences, and retreated onto her authority. "Let me put it this way, Mr. Graf. The power to approve—or disapprove—training personnel for the Cay Project is mine. Mr. Van Atta may have called you in, but I can have you removed. And I will do so without hesitation if you fail in speech or behavior to abide by psych department guidelines. I don't think I can put it any more clearly than that."

"No, you're—quite clear," Leo said.

"I'm sorry," she said sincerely. "But until you've been on the Habitat a while, you really must refrain from making snap judgments."

I'm a testing engineer, lady, thought Leo. *It's my job to make judgements all day long.* But he did not speak the thought aloud. They managed to part on a note of only slightly strained cordiality.

The entertainment vid was titled "Animals, Animals, Animals." Silver set the rerun for the "Cats" sequence for the third time.

"Again?" Claire, sharing the vid viewing chamber with her, said faintly.

"Just one more time," Silver pleaded. Her lips parted in fascination as the black Persian appeared over the vid plate, but out of deference to Claire she turned down the music and narration. The creature was crouched lapping milk from a bowl, stuck to its floor by downside gravity. The little white droplets flying off its pink tongue arced back into the dish as though magnetized.

"I wish I could have a cat. They look so soft. . . ." Silver's left lower hand reached out to pantomime-pat the life-sized image. No tactile reward, only the colored light of the holovid licking without sensation over her skin. She let her hand fall through the cat, and sighed. "Look, you can pick it up just like a baby." The vid shrank to show the cat's downsider owner carting it off in her arms. Both looked smug.

"Well, maybe they'll let you have a baby soon," offered Claire.

"It's not the same thing," said Silver. She could not help glancing a little enviously at Andy, though, curled up asleep in midair near his mother. "I wonder if I'll ever get a chance to go downside?"

"Ugh," said Claire. "Who'd want

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to? It looks so uncomfortable. Dangerous, too."

"Downsiders manage. Besides, everything interesting seems to—to come from planets." Everyone interesting, too, her thought added. She considered Mr. Van Atta's former teacher, Mr. Graf, met on her last working shift yesterday *in Hydroponics. Yet another* legged Somebody who got to go places and make things happen. He'd actually been born on old Earth, Mr. Van Atta said.

There came a muffled tap on the door of the soundproof bubble, and Silver keyed her remote control to open the door. Siggy, in the yellow shirt and shorts of Airsystems Maintenance, stuck his head through. "All clear, Silver."

"All right, come on."

Siggy slipped inside. She keyed the door shut again, and Siggy turned over, reached into the tool pouch on his belt, jimmied open a wall plate, and jammed the door's mechanism. He left the wall plate open in case of urgent need for reaccess, such as Dr. Yei knocking on the door to inquire brightly, What were they doing? Silver by this time had the back cover off the holovid. Siggy reached delicately past her to clip his homemade electronic scrambler across the power lead cable. Anyone monitoring their viewing through it would get static.

"This is a great idea," said Siggy enthusiastically.

Claire looked more doubtful. "Are you sure we won't get into a whole lot of trouble if we're caught?"

"I don't see why," said Silver. "Mr. Van Atta disconnects the smoke alarm in his quarters whenever he has a jubajoint."

"I thought downsiders weren't allowed to smoke on board," said Siggy, startled.

"Mr. Van Atta says it's a privilege of rank," said Silver. *I wish I had rank. . . .*

"Has he ever given you one of his jubas?" asked Claire in a tone of gruesome fascination.

"Once," said Silver.

"Wow," said Siggy, grinning in admiration. "What was it like?"

Silver made a face. "Not much. It tasted kind of nasty. Made my eyes red. I really couldn't see the point to it. Maybe downsiders have some biochemical reaction we don't get. I asked Mr. Van Atta, but he just laughed at me."

"Oh," said Siggy, and switched his interest to the holovid display. All three quaddies settled around it. An anticipatory silence fell in the chamber as the music swelled and the bold red title letters rotated before their eyes—"The Prisoner of Zenda."

The scene opened on an authentically-detailed street scene from the dawn of civilization, before space travel or even electricity. A quartet of glossy horses, harness jingling, drew an elaborate box on wheels across the ground.

"Can't you get any more of the 'Ninja of the Twin Stars' series?" complained Siggy. "This is more of your darned dirtball stuff. I want something realistic, like that chase scene through the asteroid belt. . . ." His hands pursued each other as he made nasal sound effects indicating machinery undergoing high acceleration.

"Shut up and look at all the animals," said Silver. "So many—and it's

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not even a zoo. The place is littered with them."

"Littered is right," giggled Claire. "They're not wearing diapers, you know. Think about that."

Siggy sniffed. "Earth must have been a really disgusting place to live, back in the old days. No wonder people grew legs. Anything, to prop them up in the air away from—"

Silver switched the vid off with a snap. "If you can't think of anything else to talk about," she said dangerously, "I'll go back to my dorm. *With* my vid. And you all can go back to watching 'Cleaning and Maintenance Techniques for Food Service Areas.' "

"Sorry." Siggy curled his four arms around himself in a submissive ball, and tried to look contrite. Claire refrained from further comment.

"Huh." Silver switched the vid back on, and continued watching in rapt and uninterrupted silence. When the railway scenes began, even Siggy stopped squirming.

Leo was well-launched into his first class lecture.

"Now, here is a typical length of electron beam weld. . . ." he fiddled with the controls of his holovid display. A ghost image in bright blue light, the computer-generated x-ray inspection record of the original object, sprang into being in the center of the room. "Spread out, kids, so you can all get a good look at it."

The quaddies arranged themselves around the display in a spherical shell of attentiveness, automatically extending helping hands to neighbors to absorb and trade momentum so that all achieved a tolerable hover. Dr. Yei, sitting in—if you could call it that—floated unobtrusively in the background. Monitoring him for his political purity, Leo supposed, not that it mattered. He did not propose to alter his lecture one jot for her presence.

Leo rotated the image so that each student could see it from every angle. "Now let's magnify this part. You see the deep-V cross section from the high-energy-density beam, familiar from your basic welding courses, right? Note the small round porosities here . . ." the magnification jumped again. "Would you say this weld is defective or not?" He almost added, *Raise your hand,* before realizing what a particularly unintelligible directive that was here. Several of the red-clad students solved the dilemma for him by crossing their upper arms formally across their chests instead, looking properly hesitant. Leo nodded toward Tony.

"Those are gas bubbles, aren't they sir? It must be defective."

Leo smiled thanks for the desired straight line. "They are indeed gas porosities. Oddly enough, though, when we crunch the numbers through, they do not appear to be defects. Let us run the computer scan down this length, with an eye to the digital read-out. As you see," the numbers flickered at a corner of the display as the cross-section moved dizzyingly, "at no point do more than two porosities appear in a cross-section, and at all points the voids occupy less than five percent of the section. Also, spherical cavities like these are the least damaging of all potential shapes of discontinuities, the least likely to propagate cracks in service. A non-

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critical defect is called a *discontinuity*." Leo paused politely while two dozen heads bent in unison to highlight this pleasingly unambiguous fact on the autotranscription of their light boards, braced between lower hands for a portable recording surface. "When I add that this weld was in a fairly low-pressure liquid storage tank, and not, for example, in a thruster propulsion chamber with its massively greater stresses, the slipperiness of this definition becomes clearer. For in a thruster the particular degree of defect that shows up here *would* have been critical."

"Now," he switched the holovid display to one in red light. "This is a holovid of the same weld from data bits mapped by an ultrasonic pulse reflective scan. Looks quite different, doesn't it? Can anyone identify *this* discontinuity?" He zoomed in on a bright area.

Several sets of arms crossed again. Leo nodded toward another student, a striking boy with aquiline nose, brilliant black eyes, wiry muscles, and dark mahogany skin contrasting elegantly with his red T-shirt and shorts. "Yes, Pramod?"

"It's an unbonded lamination?"

"Right!" Leo tapped his holovid controls. "But check down this scan —where have all our little bubbles gone? Anybody think they magically closed between tests? Thank you," he said to their knowing grins, "I'm glad you don't think that. Now let's put both maps together." Red and blue melded to purple at overlapping points as the computer integrated the two displays.

"And *now* we see the little bugger," said Leo, zooming in again. "These two porosities, plus this lamination, all in the same plane. You can see the fatal crack starting to propagate already, on this rotation—" The holovid turned, and Leo emphasized the crack with a bright pink light. "That, children, is a defect."

They oohed in gratifying fascination. Leo grinned and plunged on. "Now, here's the point. Both these test scans were valid pictures—as far as they went. But neither one was complete, neither alone sufficient. The maps were not the territories. You have to know that x-radiography is excellent for revealing voids and inclusions, but poor at finding cracks except at certain chance alignments, and ultrasound is optimum for just those laminar discontinuities x-rays are most likely to miss. Both maps, intelligently integrated, yielded a judgment."

"Now," Leo smiled a bit grimly, and replaced the gaudy image with another, monochrome green this time. "Look at this. What do you see?" He nodded at Tony again.

"A laser weld, sir."

"So it would appear. Your identification is quite understandable—and quite wrong. I want you all to memorize this piece of work. Look well. Because it may be the most evil object you ever encounter."

They looked wildly impressed, but totally bewildered. He commanded their absolute silence and utmost attention.

"*That*," he pointed for emphasis, his voice growing heavy with scorn, "is a falsified inspection record. Worse, it's one of a series. A certain subcontractor of GalacTech supplying thruster propulsion chambers for Jump ships found its profit margin endangered by a high

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volume of its work being rejected---after it had been placed in the systems. So instead of tearing the work apart and doing it over right, they chose to lean on the quality control inspectors. We will never know for certain if the chief inspector refused a bribe or not, because he wasn't around to tell us. He was found accidentally very dead due to an apparent power suit malfunction, attributed to his own errors made when attempting to don it while drunk. The autopsy found a high percentage of alcohol in his bloodstream. It was only much later that it was pointed out that the percentage was so high, he oughtn't to have been able to walk, let alone suit up.

"The assistant inspector *did* accept the bribe. The welds passed computer certification all right—because it was the same damn good weld, replicated over and over and inserted into the data bank in place of real inspections, which for the most part were never even made. Twenty propulsion chambers were put on-line. Twenty time-bombs.

"It wasn't until the second one blew up eighteen months later that the whole story was finally uncovered. This isn't hearsay; I was on the probable-cause investigating team. It was I who found it, by the oldest test in the world, eye-and-brain inspection. When I sat there in that station chair, running those hundreds of holovid records through one by one, and first recognized the piece when I saw it again—and again—and again—for the computer only recognized that the series was free of defects—and I *realized* what those bastards had done. . . ." His hands were shaking, as they always did at this point of the lecture, as the old memories flickered back. Leo clenched them by his sides.

"The judgement of the map was falsified in these electronic dream images. But the universal laws of physics yielded a judgement of blood that was absolutely real. Eighty-six people died altogether. *That,*" Leo pointed again, "was not merely fraud, it was coldest, cruelest murder."

He gathered his breath. "This is the most important thing I will ever say to you. The human mind is the ultimate testing device. You can take all the notes you want on the technical data, anything you forget you can look up again, but this must be engraved on your hearts in letters of fire.

"There is *nothing, nothing, nothing* more important to me in the men and women I train than their absolute personal integrity. Whether you function as welders or inspectors, the laws of physics are implacable lie-detectors. You may fool men. You will never fool the metal. That's all."

He let his breath out, and regained his good humor, looking around. The quaddie students were taking it with proper seriousness, good, no class cut-ups making sick jokes in the back row. In fact, they were looking rather shocked, staring at him with terrified awe.

"So," he clapped his hands together and rubbed them cheerfully, to break the spell, "now let's go over to the shop and take a beam welder apart, and see if we can find everything that can possibly go wrong with it. . . ."

They filed out obediently ahead of him, chattering among themselves again. Yei was waiting by the door aperture

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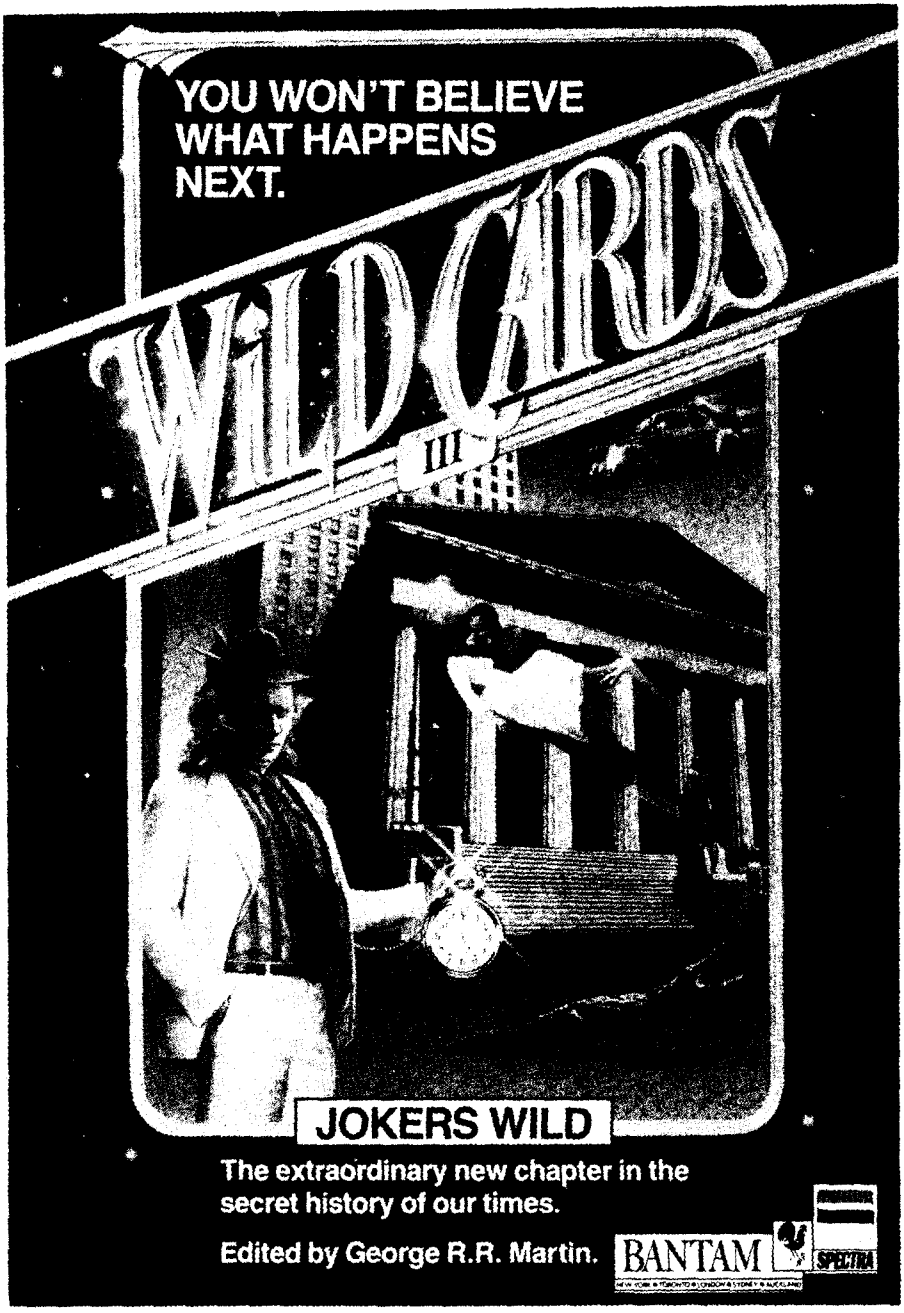

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as Leo followed his class. She gave him a brief smile.

"An impressive presentation, Mr. Graf. You become quite articulate when you talk about your work. Yesterday I thought you must be the strong silent type."

Leo flushed faintly, and shrugged. "It's not so hard, when you have something interesting to talk about."

"I would not have guessed welding engineering to be so entertaining a subject. You are a gifted enthusiast."

"I hope the quaddies were equally impressed. It's a great thing, when I can get somebody fired up. It's the greatest work in the world."

"I begin to think so. Your story. . . ." she hesitated. "Your fraud story had great impact. They've never heard anything like it. Indeed, I never heard about that one."

"It was years ago."

"Really quite disturbing, all the same." Her face bore a look of introspection. "I hope not overly so."

"Well, I hope it's very disturbing. It's a true story. I was there." He eyed her. "Someday, they may be there. Criminally negligent, if I fail to prepare them."

"Ah." She smiled shortly.

The last of his students had vanished up the corridor. "Well, I better catch up with them. Will you be sitting in on my whole course? Come on along, I'll make a welder of you yet."

She shook her head ruefully. "You actually make it sound attractive. But I'm afraid I have a full-time job. I have to turn you loose." She gave him a short nod. "You'll do all right, Mr. Graf."

* * *

CHAPTER THREE

Andy stuck out his tongue, extruding the blob of creamed rice Claire had just spooned into his mouth. "Beh," he remarked. The blob, spurned as food, apparently exerted new fascination as a plaything, for he caught it between his upper right and lower left hands as it slowly rotated off. "Eh!" he protested as his new satellite was reduced to a mere smear.

"Oh, Andy," Claire muttered in frustration, and removed the smear from his hands with a vigorous swipe from a rather soiled high-capillarity towel. "Come on, baby, you've got to try this. Dr. Yei says it's *good* for you!"

"Maybe he's full," Tony offered *helpfully*.

The nutritional experiment was taking place in Claire's private quarters, awarded her upon the birth of Andy and shared with the baby. She often missed her old dormitory mates, but reflected ruefully that the company had been right; her popularity and Andy's fascination would probably not have survived too many night feedings, diaper changes, gas attacks, mysterious diarrheas and fevers, or other infant nocturnal miseries.

Of late she'd missed Tony, too. In the last six weeks she'd hardly seen him, his new welding instructor was keeping him so busy. The pace of life seemed to be picking up all over the Habitat. There were days when there scarcely seemed to be time to draw breath.

"Maybe he doesn't like it," suggested Tony. "Have you tried mixing it with that other goo?"

"Everybody's an expert," sighed

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Claire. "Except me . . . He ate some yesterday, anyway."

"How does it taste?"

"I don't know, I never tried it."

"Hm." Tony plucked the spoon from her hand and twirled it in the opened seal-a-cup, picked up a blob, and popped it in his mouth.

"Hey—!" began Claire indignantly.

"Beh!" Tony choked. "Give me that towel." He rid himself of his sample. "No wonder he spits it out. It's Gag Station."

Claire grabbed the spoon back, muttered "Huh!" and floated over to her kitchenette to push it through the handholes to the water dispenser and give it a steaming rinse. "Germs!" she snapped accusingly at Tony.

"You try it!"

She sniffed the food cup in renewed doubt. "I'll take your word for it."

Andy in the meantime had captured his lower right hand with his uppers and was gnawing on it.

"You're not supposed to have meat yet," Claire sighed, straightening him back out. Andy inhaled, preparing for complaint, but let it go in a mere "Aah," as the door slid open revealing a new object of interest.

"How's it going, Claire?" asked Dr. Yei. Her thick useless downsider legs trailed relaxed from her hips as she pulled herself into the cabin.

Claire brightened. She liked Dr. Yei; things always seemed to calm down a bit when she was around. "Andy won't eat the creamed rice. He liked the strained banana well enough."

"Well, next feeding try introducing the oatmeal instead," said Dr. Yei. She floated over to Andy, held out her hand; he captured it with his uppers. She peeled off his hands, held her hand down further; he grasped at it with his lowers, and giggled. "His lower body coordination is coming along nicely. Bet it will nearly match the upper by his first birthday."

"And that fourth tooth broke through day before yesterday," said Claire, pointing it out.

"Nature's way of telling you it's time to eat creamed rice," Dr. Yei lectured the baby with mock seriousness. He clamped to her arm, beady eyes intent upon her gold loop earrings, nutrition quite forgotten. "Don't fret too much, Claire. There's always this tendency to push things with the first child, just to reassure yourself it can all be done. It will be more relaxed with the second. I guarantee all babies master creamed rice before they're twenty no matter *what* you do."

Claire laughed, secretly relieved. "It's just that Mr. Van Atta was asking about his progress."

"Ah." Dr. Yei's lips twitched in a rather compressed smile. "I see." She defended her earring from a determined assault by placing Andy in air just beyond reach. A frustrated paroxysm of swimming-motions gave him only an unwanted spin. He opened his mouth to howl protest; Dr. Yei surrendered instantly, but bought time by holding out just her fingertips.

Andy again headed earring-ward, hand over hand over hand. "Yeah, go for it, baby," Tony cheered him on.

"Well," Dr. Yei turned her attention to Claire. "I actually stopped by to pass on some good news. The company is so pleased with the way things have

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turned out with Andy, they've decided to move up the date for you to start your second pregnancy."

Tony's face split in a delighted grin, beyond Dr. Yei's shoulder. His upper hands clasped in a gesture of victory. Claire made embarrassed-suppression motions at him, but couldn't help grinning back.

"Wow," said Claire, warm with pleasure. So, the company thought she was doing *that* well. There had been down days when she'd thought no one noticed how hard she'd been trying. "How much up?"

"Your monthly cycles are still being suppressed by the breast feeding, right? You have an appointment at the infirmary tomorrow morning. Dr. Minchenko will give you some medicine to start them up again. You can start trying on the second cycle."

"Oh my goodness. That soon." Claire paused, watching the wriggling Andy and remembering how the first pregnancy had drained her energy. "I guess I can handle it. But whatever happened to that two-and-a-quarter year ideal spacing you were talking about?"

Dr. Yei bit her words off carefully. "There is a Project-wide push to increase productivity. In all areas." Dr. Yei, always straightforward in Claire's experience, smiled falsely. She glanced at Tony, hovering happily, and pursed her lips.

"I'm glad you're here, Tony, because I have some good news for you, too. Your welding instructor, Mr. Graf, has rated you tops in his class. So you've been picked as gang foreman to go out on the first Cay Project contract GalacTech has landed. You and your coworkers will be shipping out in about a month to a place called Kline Station It's on the far end of the wormhole nexus, beyond Earth, and it's a long ride, so Mr. Graf will be going along to complete your training en route, and double as engineering supervisor."

Tony surged across the room in excitement. "At last! Real work! But—" he paused, stricken. Claire, one thought ahead of him, felt her face becoming mask-like. "But how's Claire supposed to start a baby next month if I'm on my way to where?"

"Dr. Minchenko will freeze a couple of sperm samples before you go," suggested Claire. "Won't he. . . ?"

"Ah—hm," said Dr. Yei. "Well, actually, that wasn't in the plans. Your next baby is scheduled to be fathered by Rudy, in Microsystems Installation."

"Oh, no!" gasped Claire.

Dr. Yei studied both their faces, and arranged her mouth in a severe frown. "Rudy is a very nice boy. He would be very hurt by that reaction, I'm sure. This can't be a surprise, Claire, after all our talks."

"Yes, but—I was hoping, since Tony and I did so well, they'd let us—I was going to ask Dr. Cay!"

"Who is no longer with us," Dr. Yei sighed. "And so you've gone and let yourselves become pair-bonded. I warned you not to do that, didn't I?"

Claire hung her head. Tony's face was mask-like, now.

"Claire, Tony, I know this seems hard. But you in the first generation have a special burden. You are the first step in a very detailed long-range plan for GalacTech, spanning literally gen-

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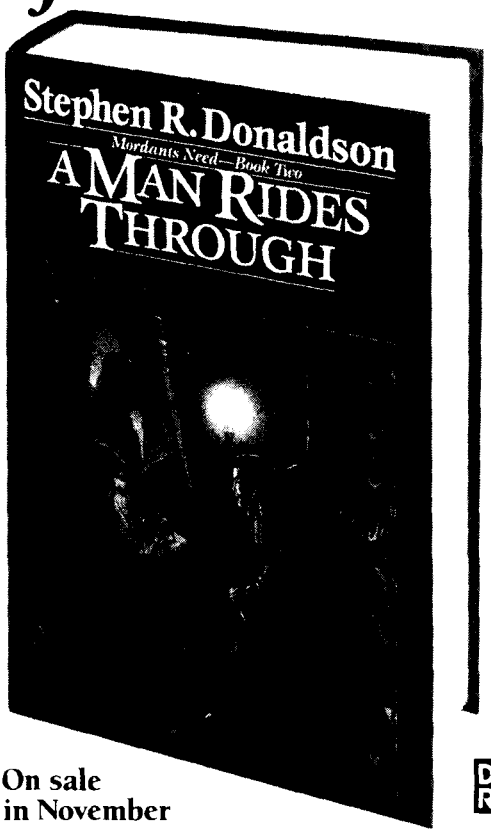

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erations. Your actions have a multiplier effect all out of proportion—look, this isn't by any means the end of the world for you two. Claire has a long reproductive career scheduled. It's quite probable you'll be getting back together again someday. And you, Tony—you're tops. GalacTech's not going to waste you, either. There will be other girls—''

''I don't want other girls,'' said Tony stonily. ''Only Claire.''

Dr. Yei paused, went on. ''I shouldn't be telling you this yet, but Sinda in Nutrition is next for you. I've always thought she was an extraordinarily pretty girl.''

''She has a laugh like a hacksaw.''

Dr. Yei blew out her breath impatiently. ''We'll discuss it later. At length. Right now I *have* to talk with Claire.'' She thrust him firmly out the door and keyed it shut on his frown and muffled objections.

Dr. Yei turned back to Claire and fixed her with a stern gaze. ''Claire—did you and Tony continue to have sexual relations after you became pregnant?''

''Dr. Minchenko said it wouldn't hurt the baby.''

''Dr. Minchenko knew?''

''I don't know. . . . I just asked him, like, in a general way.'' Claire studied her hands guiltily. ''Did you expect us to stop?''

''Well, yes!''

''You didn't tell us to.''

''You didn't ask. In fact, you were quite careful not to bring up the subject, now that I think back—oh, how could I have been so blind-sided?''

''But downsiders do it all the time,'' Claire defended herself.

''How do you know what downsiders do?''

''Silver says Mr. Van Atta—'' Claire stopped abruptly.

Dr. Yei's attention sharpened, knife-like and uncomfortable. ''What do you know about Silver and Mr. Van Atta?''

''Well—everything, I guess. I mean, we all wanted to know how downsiders did it.'' Claire paused. ''Downsiders are *strange*,'' she added.

After a paralyzed moment, Dr. Yei buried her suffused face in her hands and sniggered helplessly. ''And so Silver's been supplying you with detailed information?''

''Well, yes.'' Claire regarded the psychologist with wary fascination.

Dr. Yei stifled her chortles, a strange light growing in her eyes, part humor, part irritation. ''I suppose—I suppose you'd better pass the word to Tony not to let on. I'm afraid Mr. Van Atta would become a little upset, if he realized his personal activities had a second-hand audience.''

''All right,'' Claire agreed doubtfully. ''But—you always wanted to know all about me and Tony.''

''That's different. We were trying to help you.''

''Well, we and Silver are trying to help each other.''

''You're not supposed to help yourselves.'' The sting of Dr. Yei's criticism was blunted by her suppressed smile. ''You're supposed to wait until you're served.'' Yei paused. ''Just how many of you are privy to this, ah, Silver-mine of information, anyway? Just you and Tony, I trust?''

''Well, and my dormitory mates. I take Andy over there in my off hours

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and we all play with him. I used to have my sleep restraints opposite Silver's until I moved out. She's my best friend. Silver's so—so brave, I guess—she'll try things I'd never dare." Claire sighed envy.

"Eight girls," Yei muttered. "Oh, lord Krishna . . . I trust none of them have been inspired to emulation yet?"

Claire, not wishing to lie, said nothing. She didn't need to; the psychologist, watching her face, winced.

Yei turned indecisively in air. "I've got to have a talk with Silver. I should have done it when I first suspected—but I thought the man had the wit not to contaminate the experiment—asleep on my feet. Look, Claire, I want to talk with you more about your new assignment. I'm here to try and make it as easy and pleasant as possible—you know I'll help, right? I'll get back to you as soon as I can."

Yei peeled Andy off her neck where he was now attempting to taste her earring and handed him back to Claire, and exited the airseal door muttering something about "—containing the damage . . ."

Claire, alone, held her baby close. Her troubled uncertainty turned like a lump of metal under her heart. She had tried so hard to be good. . . .

Leo squinted approvingly against the harsh light and dense shadows of the vacuum as a pair of his space-suited students horsed the locking ring accurately into place on the end of its flex tube. Between the two of them their eight gloved hands made short work of the task.

"Now Pramod, Bobbi, bring up the beam welder and the recorder and put them in their starting position. Julian, you run the optical laser alignment program and lock them on."

A dozen of the four-armed figures, their names and numbers printed in large clear figures on the front of each helmet and across the backs of their silvery work suits, bobbed about. Their suit jets puffed as they jockeyed for a better view.

"Now, in these high-energy-density partial penetration welds," Leo lectured into his spacesuit's audio pick-up, "the electron beam must not be allowed to achieve a penetrating steady-state. This beam can punch through half a meter of steel. Even one spiking event and your, say, nuclear pressure vessel or your propulsion chamber can lose its structural integrity. Now, the pulser that Pramod is checking right now—" Leo made his voice heavy with hint; Pramod jerked, and hastily began punching up the system read-out on his machine, "utilizes the natural oscillation of the point of beam impingement within the weld cavity to set up a pulsing schedule that maintains its frequency, eliminating the spiking problem. *Always* double check its function before you start."

The locking ring was firmly welded to its flex tube and duly examined for flaws by eye, hologram scan, eddy current, the examination and comparison of the simultaneous x-ray emission recording, and the classic kick-and-jerk test. Leo prepared to move his students on to the next task.

"Tony, you bring the beam welder over—TURN IT OFF FIRST!" Feedback squeal lanced through everyone's earphones, and Leo modulated his voice

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from his first urgent panicked bellow. The beam had in fact been off, but the controls live; one accidental bump, as Tony swung the machine around, and—Leo's eye traced the hypothetical slice through the nearby wing of the Habitat, and he shuddered.

"Get your head out of your ass, Tony! I saw a man cut in half by one of his friends once by just that careless trick."

"Sorry . . . thought it would save time . . . sorry . . ." Tony mumbled.

"You know better." Leo calmed, as his heart stopped palpitating. "In this hard vacuum that beam won't stop till it hits the third moon, or whatever it might encounter in between." He almost continued, stopped himself; no, not over the public comm channel. Later.

Later, as his students unsuited in the equipment locker, laughing and joking as they cleaned and stored their work suits, Leo drifted over to the silent and pale Tony. Surely I didn't bark at him *that* hard, Leo thought to himself. Figured he was more resilient . . . "Stop and see me when you're finished here," said Leo quietly.

Tony flinched guiltily. "Yes, sir."

After his fellows had all swooped out, eager for their end-of-shift meal, Tony hung in air, both sets of arms crossed protectively across his torso. Leo floated near, and spoke in a grave tone.

"Where were you, out there today?"

"Sorry, sir. It won't happen again."

"It's been happening all week. You got something on your mind, boy?"

Tony shook his head. "Nothing—nothing to do with you, sir."

Meaning, nothing to do with work, Leo interpreted that. All right, so. "If it's taking your mind off your work, it does have something to do with me. Want to talk about it? You got girl trouble? Little Andy all right? You have a fight with somebody?"

Tony's blue eyes searched Leo's face in sudden uncertainty, then he grew closed and inward once again. "No, sir."

"You worried about going out on that contract? I guess it will be the first time away from home for you kids, at that."

"It's not that," denied Tony. He paused, watching Leo again. "Sir—are there a great many other companies out there besides ours?"

"Not a great many, for deep interstellar work," Leo replied, a little baffled by this new turn in the conversation. "We're the biggest, of course, though there's maybe a half dozen others that can give us some real competition. In the heavily populated systems, like Tau Ceti or Escobar or Orient or of course Earth, there's always alot of little companies operating on a smaller scale. Super-specialists, or entrepreneurial mavericks, this and that. The outer worlds are coming on strong lately."

"So—so if you ever quit GalacTech, you could get another job in space."

"Oh, sure. I've even had offers—but our company does the most of the sort of work I want to do, so there's no reason to go elsewhere. And I've got a lot of seniority accumulated by now, and all that goes with it. I'll probably be with GalacTech till I retire, if I don't die in harness." *Probably from a heart attack brought on by watching one of my students try to accidentally kill himself.* Leo did not speak the thought

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aloud; Tony seemed chastised enough. But still abstracted.

"Sir . . . tell me about *money*."

"Money?" Leo raised his brows. "What's to tell? The stuff of life."

"I've never seen any—I'd understood it was sort of coded value-markers, to, to facilitate trade, and keep count."

"That's right."

"How do you get it?"

"Well—most people work for it. They, ah, trade their labor for it. Or if they own or manufacture or grow something, they can sell it. I work."

"And GalacTech gives you *money?*"

"Uh, yes."

"If I asked, would the company give me money?"

"Ah. . . ." Leo became conscious of skating on very thin ice. His private opinion of the whole Cay Project had perhaps better remain just that, while he ate the company's bread. His job was to teach safe quality welding procedures, not—foment union demands, or whatever this conversation was sliding toward. "Whatever would you spend it on, up here? GalacTech gives you everything you need. Now, when I'm downside, or not on a company installation, I have to buy my own food, clothing, travel and what-not. Besides," Leo reached for a less queasily specious argument, "up till now, you haven't actually done any work for GalacTech, although it's done plenty for you. Wait till you've actually been out on a contract and done some real producing. Then maybe it might be time to talk about money." Leo smiled, feeling hypocritical, but at least loyal.

"Oh." Tony seemed to fold inward on some secret disappointment. His blue eyes flicked up, probing Leo again. "When one of the company Jump ships leaves Rodeo—where does it go first?"

"Depends on where it's wanted, I guess. Some run straight all the way to Earth. If there's cargo or people to divide up for other destinations, the first stop is usually Orient Station."

"GalacTech doesn't own Orient Station, does it?"

"No, it's owned by the government of Orient IV. Although GalacTech leases a good quarter of it."

"How long does it take to get to Orient Station from Rodeo?"

"Oh, usually about a week. You'll probably be stopping there yourself quite soon, if only to pick up extra equipment and supplies, when you're sent out on your first construction contract."

The boy was looking more outer-directed now, perhaps thinking about his first interstellar trip. That was better. Leo relaxed slightly.

"I'll be looking forward to that, sir."

"Right. If you don't cut your foot, er, hand off meanwhile, eh?"

Tony ducked his head and grinned. "I'll try not to, sir."

And what was that all about? Leo wondered, watching Tony sail out the door. Surely the boy could not be thinking of trying to strike out on his own? Tony had not the least conception of what a freak he would seem, beyond his familiar Habitat. If he would only open up a little more. . . .

Leo shrank from the thought of confronting him. Every downsider staff member in the Habitat seemed to feel they had a right to the quaddies' per-

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sonal thoughts. There wasn't a lockable door anywhere in the quaddies' living quarters. They had all the privacy of ants under glass.

He shook off the critical thought, but could not shake off his queasiness. All his life he had placed his faith in his own technical integrity—if he followed that star, his feet would not stumble. It was ingrained habit by now, he had brought that technical integrity to the teaching of Tony's work gang almost automatically. And yet . . . this time, it did not seem to be quite enough. As if he had memorized the answer, only to discover the question had been changed.

Yet what more could be demanded of him? What more could he be expected to give? What, after all, could one man do?

A spasm of vague fear made him blink, the hard-edged stars in the viewport smeared, as the looming shadow of the dilemma clouded on the horizon of his conscience. *More* . . .

He shivered, and turned his back to the vastness. It could swallow a man, surely.

Ti, the freight shuttle co-pilot, had his eyes closed. Perhaps that was natural at times like this, Silver thought, studying his face from a distance of ten centimeters. At this range her eyes could no longer superimpose their stereoscopic images, so his twinned face overlapped itself. If she squinted just right, she could make him appear to have three eyes. Men really were rather alien. Yet the metal contact implanted in his forehead, echoed at both temples, did not have that effect, seeming more a decoration or a mark of rank. She blinked one eye closed, then the other, causing his face to shift back and forth in her vision.

Ti opened his eyes a moment, and Silver quickly flinched into action. She smiled, half-closed her own eyes, picked up the rhythm of her flexing hips. "Oooh," she murmured, as Van Atta had taught her. *Let's hear some feedback, honey*, Van Atta had demanded, so she'd hit on a collection of noises that seemed to please him. They worked on the pilot, too, when she remembered to make them.

Ti's eyes squeezed shut, his lips parting as his breath came faster, and Silver's face relaxed into pensive stillness once again, grateful for the privacy. Anyway, Ti's gaze didn't make her as uncomfortable as Mr. Van Atta's, that always seemed to suggest that she ought to be doing something else, or more, or differently.

The pilot's forehead was damp with sweat, plastering down one curl of brown hair around the shiny plug. Mechanical mutant, biological mutant, equally touched by differing technologies; perhaps that was why Ti had first seen her as approachable, being an odd man out himself. Both freaks together. On the other hand, maybe the Jump pilot just wasn't very fussy.

He shivered, gasped convulsively, clutched her tightly to his body. Actually, he looked—rather vulnerable. Mr. Van Atta never looked vulnerable at this moment. Silver was not sure just what it was he did look like.

What's he getting out of this that I'm not? Silver wondered. What's wrong with me? Maybe she really was, as Van

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Atta had once accused, frigid—an unpleasant word, it reminded her of machinery, and the trash dumps locked outside the Habitat—so she had learned to make noises for him, and twitch pleasingly, and he had commended her for loosening up.

Silver reminded herself that she had another reason for keeping her eyes open. She glanced again past the pilot's head. The observation window of the darkened control booth where they trysted overlooked the freight loading bay. The staging area between the bay's control booth and the entrance to the freight shuttle's hatch remained dimly lit and empty of movement. *Hurry up Tony, Claire,* Silver thought worriedly. *I can't keep this guy occupied all shift.*

"Wow," breathed Ti, coming out of his trance and opening his eyes and grinning. "When they designed you folks for free fall they thought of *everything.*" He released his own clutch on the wings of Silver's shoulderblades to slide his hands down her back, around her hips, and along her lower arms, ending with an approving pat on her hands locked around his muscular downsider flanks. "*Truly* functional."

"How *do* downsiders keep from, um, bouncing apart?" Silver inquired curiously, taking practical advantage of having cornered an apparent expert on the subject.

His grin widened. "Gravity keeps us together."

"How strange. I always thought of gravity as something you had to fight all the time."

"No, only half the time. The other half, it works for you," he assured her.

He undocked from her body rather gracefully—perhaps it was all that piloting experience showing through—and planted a kiss in the hollow of her throat. "Pretty lady."

Silver blushed a little, grateful for the dim lighting. Ti turned his attention momentarily to a necessary clean-up chore. A quick whistle of air, and the spermicide-permeated condom was gone down the waste chute. Silver suppressed a faint twinge of regret. It was just too bad Ti wasn't one of them. Too bad she was such a long way down the roster of those scheduled for motherhood. Too bad. . . .

"Did you find out from your doctor fellow if we really need those?" Ti asked her.

"I couldn't exactly ask Dr. Minchenko directly," Silver replied. "But I gather he thinks any conceptus between a downsider and one of us would abort spontaneously, pretty early on—but nobody knows for sure. Could be a baby might make it to birth with lower limbs that were neither arms nor legs, but just some mess in between." *And they probably wouldn't let me keep it. . . .* "Anyway, it saves chasing body fluids around the room with a hand vac."

"Too true. Well, I'm certainly not ready to be a daddy."

How incomprehensible, thought Silver, for a man that old. Ti must be at least twenty-five, much older than Tony, who was nearly the eldest of them all. . . . She was careful to float facing the window, so that the pilot had his back to it. *Come on, Tony, do it if you're going to . . .*

A cool draft from the ventilators raised goose bumps on all her arms, and Silver shivered.

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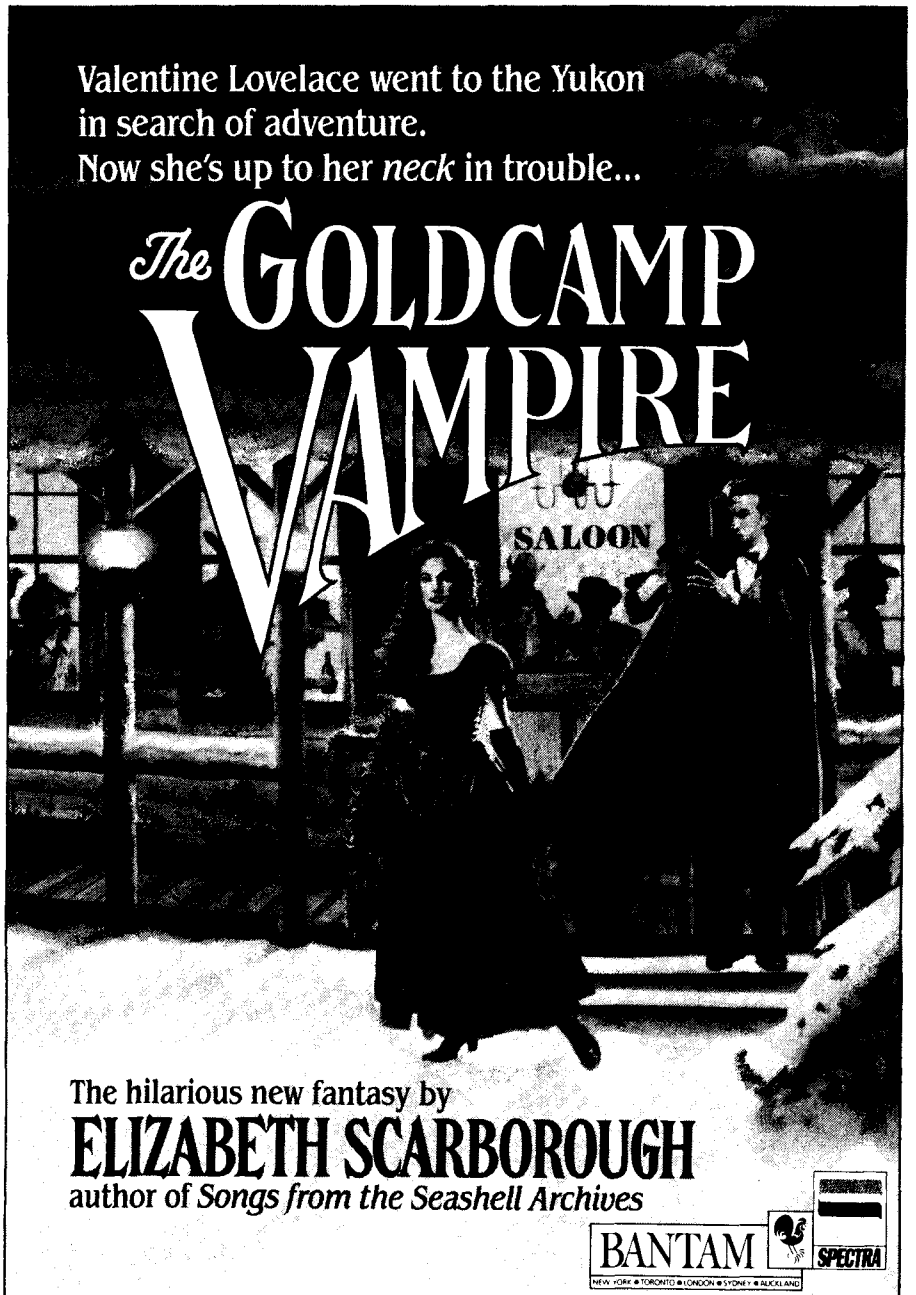
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"Chilly?" Ti asked solicitously, and rubbed his hands up and down her arms rapidly to warm them by friction, then retrieved her blue shirt and shorts from the side of the room where they had drifted. Silver shrugged into them gratefully. The pilot dressed too, and Silver watched with covert fascination as he fastened his shoes. Such inflexible, heavy coverings, but then feet were inflexible, heavy things in their own right. She hoped he'd be careful how he swung them around. Shod, his feet reminded her of mallets.

Ti, smiling, unhooked his flight bag from a wall rack where he had stowed it when they'd retreated to the control booth half an hour earlier. "Gotcha something."

Silver perked up, and her four hands clasped each other hopefully. "Oh! Were you able to find any more book-discs by the same lady?"

"Yes, here you go—" Ti produced some thin squares of plastic from the inner reaches of his flight bag. "Three titles, all new."

Silver pounced on them, and read their labels eagerly. Rainbow Illustrated Romances: *Sir Randan's Folly, Love in the Gazebo, Sir Randan and the Bartered Bride,* all by Valeria Virga. "Oh, wonderful!" She wrapped her upper right arm around Ti's neck and gave him a quite spontaneous and vigorous kiss.

He shook his head in mock despair. "I don't know how you can read that dreck. I think the author is a committee, anyway."

"It's *great!*" Silver defended her beloved literature indignantly. "It's so, so full of color, and strange places and times—a lot of them are set on old Earth, way back when *everybody* was still downside—they're amazing. People kept animals all around them—these enormous creatures called horses actually used to carry them around on their backs. I suppose the gravity tired people out. And these rich people, like—like company executives, I guess—called 'lords' and 'nobles' lived in the most fantastic habitats, stuck to the surface of the planet—and there was *nothing* about all this in the history *we* were taught!" her indignation peaked.

"That stuff's not history, though," he objected. "It's fiction."

"It's nothing like the fiction they give us, either. Oh, it's all right for the little kids—I used to love *The Little Compressor That Could*—we made our crèche-mother read it over and over. And the Bobby BX-99 series was all right . . . *Bobby BX-99 Solves the Excess Humidity Mystery . . . Bobby BX-99 and the Plant Virus* . . . it was then I asked to specialize in Hydroponics. But downsiders are ever so much more interesting to read about. It's so —so—when I'm reading this," she clutched the little plastic squares tightly, "it's like they're real, and I'm not." Silver sighed hugely.

Although perhaps Mr. Van Atta *was* a bit like Sir Randan . . . high of status, commanding, short-tempered . . . Silver wondered briefly why short temper in Sir Randan always seemed so exciting and attractive, full of fascinating consequences. When Mr. Van Atta became angry, it merely made her sick to her stomach. Perhaps downsider women had more courage.

Ti shrugged baffled amusement. "Whatever turns you on, I guess. Can't

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see the harm in it. But I brought something better for you, this trip—" he rummaged in his flight bag again, and shook out a froth of ivory fabric, intricate lace and ribbony satin. "I figured you could wear a regular woman's blouse all right. It's got flowers in the pattern, thought you'd like that, being in hydroponics and all."

"Oh . . ." One of Valeria Virga's heroines might have been at home in such a garment. Silver reached for it, drew her hand back. "But—but I can't take it."

"Why not? You take the book-discs. It wasn't *that* expensive."

Silver, who felt she was beginning to have a fairly clear idea of how money worked from her reading, shook her head. "It's not that. It's well—you know, I don't think Dr. Yei would approve of our meeting like this. Neither would—would a lot of other people." Actually, Silver was fairly sure that "disapprove" would barely begin to cover the consequences should her secret transactions with Ti be found out.

"Prudes," scoffed Ti. "You're not going to let them start telling you what to do *now*, are you?" But his scorn was tinged with anxiety.

"I'm not going to start telling them what I *am* doing either," said Silver pointedly. "Are you?"

"God, no," he waved his hands in horrified negation.

"So, we are in agreement. Unfortunately, that," she pointed regretfully at the blouse, "is something I can't hide. I couldn't wear it without someone demanding that I explain where I got it."

"Oh," he said, in the blunted tone of one struck by incontrovertible fact. "Yeah, I—guess I should have thought of that. Do you suppose you could put it away for a time? I've only been taking my gravity leaves on the Rodeo side because all the shuttle bonus berths at Orient IV get nailed by the senior guys. Well, and you can log a lot more hours here faster, with all the freight hauling. But I'll have my shuttle commander's rating and be back to permanent Jump status in just a few more cycles."

"It can't be shared, either," said Silver. "You see, the thing about the books and the vid dramas and things, besides being small and easy to hide, is that they can be passed all around the group without being used up. Nobody gets left out. So I can get, um, a lot of cooperation when I want to, say—get away for a little time by myself?" A toss of her head indicated the privacy they were presently enjoying.

"Ah," gulped Ti. He paused. "I—hadn't realized you were passing the stuff around."

"Not share?" said Silver. "That would be *really* wrong." She stared at him in mild offense, and pushed the blouse back toward him on the surge of the emotion, quickly, before she weakened. She almost explained further, then thought better of it.

Best Ti didn't know about the uproar when one of the book-discs, accidently left in a viewer, had been found by one of the Habitat's downsider staff and turned over to Dr. Yei. The search—barely alerted—they had scrambled successfully to hide the rest of the contraband library, but the fierce intensity of the search had been warning enough to Silver of how serious was her offense in the eyes of her authorities. There had

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been two more surprise inspections since, even though no more discs had been found. She could take a hint.

Mr. Van Atta himself had taken her aside—her!—and urged her to spy out the leak for him among her comrades. She had started to confess, stopped just in time, as his rising rage tightened her throat with fear. "I'm going to crucify the little sneak when I get my hands on him," Van Atta had snarled. Maybe Ti would not find Mr. Van Atta and Dr. Yei and all their staffs ranked together so intimidating—but she dared not risk losing her one sure source of downsider delights. Ti at least was willing to barter for what was in effect a bit of Silver's labor, the one invisible commodity not accounted for in any inventory; who knew, another pilot might want *things* of some kind, far more difficult to smuggle out of the Habitat unnoticed.

A long-awaited movement in the loading area caught her eye. And you thought you were risking trouble for a few books, Silver thought to herself. Wait'll *this* shit gets on the loose . . .

"Thank you anyway," said Silver hastily, and grabbed Ti around the neck for a prolonged thank-you kiss. He closed his eyes—wonderful reflex, that—and Silver rolled hers toward the view out the control booth window. Tony, Claire, and Andy were just disappearing into the shuttle hatch flex tube.

There, thought Silver, that's it. I've done what I can—the rest is up to you. Good luck, double-luck. And more sharply, *I wish I was going with you.*

"Oof! Look at the time!" Ti broke off their embrace. "I've got to get this checklist completed before Captain Durrance gets back. Guess you're right about the shirt," he stuffed it unceremoniously back into his flight bag, "What *do* you want me to bring you next time?"

"Siggy in Airsystems Maintenance asked me if there were any more holovids in the *Ninja of the Twin Stars* series," Silver said promptly. "He's up to Number 7, but he's missing 4 and 5."

"Ah," said Ti "now that was decent entertainment. Did you watch them yourself?"

"Yes," Silver wrinkled her nose, "but I'm not sure—the people in them did such horrible things to one another—they are fiction, you say?"

"Well, yes."

"That's a relief."

"Yes, but what would you like for yourself?" he persisted. "I'm not risking reprimand to gratify Siggy, whoever he is. Siggy doesn't have your," he sighed in remembered pleasure, "dear double-jointed hips."

Silver fanned out the three new book cards in her lower right hand. "More, please, sir."

"If it's dreck you want," he captured each of her hands in turn and kissed their palms, "it's dreck you shall have. Uh, oh, here comes my fearless Captain." Ti hastily straightened his shuttle pilot's uniform, turned up the light level, and picked up his report panel as an airseal door at the far end of the loading bay swished open. "He hates being saddle with junior Jumpers. Tadpoles, he calls us. I think he's uncomfortable because on my Jumpship, I'd outrank him. Still, better not give the old guy something to pick on. . . ."

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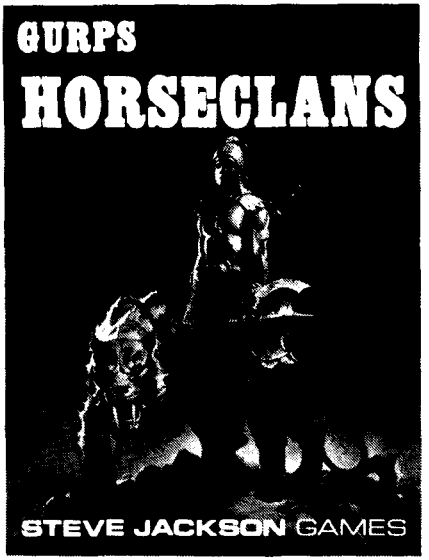

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Silver made the book cards disappear into her work bag and took up the pose of an idle bystander as Captain Durrance, the shuttle commander, floated into the control booth.

"Snap it up, Ti, we've had a change of itinerary," said Captain Durrance.

"Yes, sir. What's up?"

"We're wanted downside."

"Hell," Ti swore mildly. "What a pain. I had a hot date lined—er," his eye fell on Silver, "was supposed to meet a friend for dinner tonight at the Transfer Station."

"Fine," said Captain Durrance, ironically unsympathetic. "File a complaint with Employee Relations, your work schedule is interfering with your love life. Maybe they can arrange that you not have a work schedule."

Ti took the hint, and moved hastily out to continue his duties as a Habitat technician arrived to take over the loading bay control booth.

Silver made herself small in a corner, frozen in horror and confusion. At the Transfer Station, Tony and Claire had planned to stow away on a Jump ship for Orient IV, get beyond the reach of GalacTech, find work when they got there; a horribly risky plan, in Silver's estimation, a measure of their desperation. Claire had been terrified, but at last persuaded by Tony's plan of carefully-thought-out stages. At least, the first stages had been carefully thought-out; they had seemed to get vaguer, farther away from Rodeo and home. They had not planned on a downside detour in any version.

Tony and Claire had surely hidden themselves by now in the shuttle's cargo bay. There was no way for Silver to warn them—should she betray them to save them? The ensuing uproar was guaranteed to be ghastly—her dismay wrapped like a steel band around her chest, constricting breathing, constricting speech.

She watched on the control booth's vid display in miserable paralysis as the shuttle kicked away from the Habitat and began to drop toward Rodeo's swirling atmosphere.

CHAPTER FOUR

The dim cargo bay seemed to groan all around Claire as deceleration strained its structure. Buffeting, accompanied by a hissing whistle, vibrated through the shuttle's metal skin.

"*What's wrong?*" *gasped Claire.* She released an anchoring hand on the plastic crate behind which they had hidden to double her grasp on Andy and hold him closer. "Are we sideswiping something? What's that funny noise?"

Tony hurriedly licked a finger and held it out. "No draft to speak of." He swallowed, testing his eustachian tubes. "We're not depressurizing." Yet the whistle was rising.

Two mechanical ka-chunks, one after the other, that were nothing at all like the familiar thump and click of a hatch seal seating itself properly, shot terror through Claire. The deceleration went on and on, much too long, confused by a strange new vector of thrust that seemed to emanate from the shuttle's ventral side. The side of the cargo bay to which the crates were anchored seemed to push against her. She nervously put her back to it, and cushioned Andy upon her belly.

The baby's eyes were round, his

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mouth an echoing "o" of bewilderment. *No, please, don't start crying!* She dared not release the cry locked in her own throat, it would set him off like a siren. "Patty cake, patty cake, baker's man," Claire choked. "Microwave a cake as fast as you can . . ." She tickled his cheek, flicking her eyes at Tony in mute appeal.

Tony's face was white. "Claire—I think this shuttle's going downside! I bet those bangs were the airfoils deploying."

"Oh, no! Can't be. Silver checked the schedule—"

"It looks like Silver made a big mistake."

"I checked it too. This shuttle was supposed to be picking up a load of stuff at the Transfer Station, *then* going downside."

"Then you *both* made a big mistake." Tony's voice was harsh and shaking, anger masking fear.

Oh, help, don't yell at me—if I don't stay calm, neither will Andy—this wasn't my idea. . . .

Tony rolled over on his stomach and levered his body away from the thrusting surface of the—the *floor*, downsiders called the direction from which the vector of gravitational force came—and crept to the nearest window, pulling himself alongside it. The light that poured through it was taking on a strange diffuse quality, diminishing. "It's all white—Claire, I think we must be entering a cloud!"

Claire had watched clouds from orbit above for hours, as they slowly billowed in the convection of Rodeo's atmosphere. They had always seemed massive as moons. She longed to go look.

"If there was a Fort Knox for science fiction writers who really matter, we'd have to lock Haldeman up there."

—*Stephen King*

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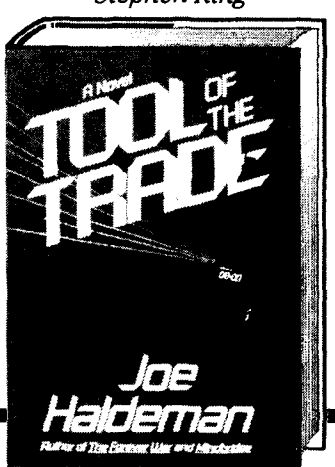

William Morrow

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Andy was clutching her blue T-shirt. She rolled over, as Tony had, palms to the surface, and pushed up. Andy, turning his head toward his father, reached out with his upper hands and tried to shove off from Claire with his lowers. The floor leaped up and smacked him.

For a moment he was too stunned to howl. Then his little mouth went from round to square and poured out the vibrating scream of true pain. The sound knifed through every nerve in Claire's body.

Tony, too, jerked at the noise, and scrambled down from the window and back toward them. "Why did you drop him? What do you think you're doing? Oh, make him be quiet, quick!"

Claire rolled onto her back again, pulling Andy onto the elastic softness of her abdomen, and patted and kissed him frantically. The timbre of his screams began to change from the frightening high-pitched cry of pain to the less piercing bellows of indignation, but the volume was just as loud.

"They'll hear him all the way up in the pilot's compartment!" Tony hissed in anguish. "*Do* something!"

"I'm *trying*," Claire hissed back. Her hands shook. She tried to push Andy's head toward her breast, standard comfort, but he turned his head away and screamed louder. Fortunately, the sound of the atmosphere rushing over the shuttle's skin had risen to a deafening thunder. By the time the noise peaked and faded, Andy's cries had become whimpering hiccups. He rubbed his face, slimy with tears and mucous, mournfully against Claire's T-shirt. His weight on Claire's stomach and diaphragm half-stopped her breath, but she dared not lay him down.

Another set of clunks reverberated through the shuttle. The engines' vibrations changed their pitch, and Claire was plucked this way and that by changing acceleration vectors, none as strong as the one emanating from the floor. She spared the two hands from comforting Andy to brace herself against the plastic crates.

Tony lay beside them, biting his lips in helpless anxiety. "We must be coming down to land on the surface."

Claire nodded. "At one of the shuttleports. There'll be people there—downsiders—maybe we can tell them we got trapped aboard this shuttle by accident. Maybe," she added hopefully, "they'll send us right back up home."

Tony's right upper hand clenched. "No! We can't give up now! We'd never get another chance!"

"But what else can we do?"

"We'll sneak off this ship and hide, until we can get on another one, one that's going to the Transfer Station." His voice turned earnest with urgent pleading as a puff of dismay escaped Claire's parted lips. "We did it once, we can do it again."

She shook her head doubtfully. Further argument was interrupted by a startling series of thumps that shook the whole ship and then blended into a low continuous rumble. The light falling through the window shifted its beam around the cargo bay as the shuttle landed, taxied, and turned. Then it winked out, the cargo bay dimmed, and the engines whined to an equally startling silence.

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Claire cautiously unbraced herself. Of all the acceleration vectors, only one remained. Isolated, it became overwhelming.

Gravity. Silent, implacable, it pressed against her back—she struggled with a nasty illusion that it might suddenly cease, and the thrust it imparted slammed her into the ceiling above, smashing Andy between. In an accompanying optical illusion, the whole cargo bay seemed to be chugging in a slow circle around her. She closed her eyes in self-defense.

Tony's hand tightened warningly on her left lower wrist. She looked up and froze as the outside cargo bay door at the forward end of the compartment slid open.

A pair of downsiders wearing company maintenance coveralls entered. The access door in the center of the shuttle's fuselage dilated, and Ti the shuttle co-pilot stuck his head through.

"Hi, guys. What's the big rush-rush?"

"We're supposed to have this bird turned around and reloaded in an hour, that's what," replied the maintenance man. "*You* have just time to pee and eat lunch."

"What's the cargo? I haven't seen this much hopping around since the last medical emergency."

"Equipment and supplies for some sort of show they're supposed to be putting on up at your Habitat for the Vice President of Operations."

"That's not till next week."

The maintenance man snickered. "That's what everybody thought. The VP just blew in a week early on her private courier, with a whole commando squad of accountants. Seems she likes

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surprise inspections. Management, naturally, is overjoyed."

"Don't laugh too soon," Ti warned. "Management has ways of sharing its joy with the rest of us."

"Don't I know it," the maintenance man groaned. "C'mon, c'mon, you're blocking the door . . ." The three of them clattered forward.

"*Now,*" whispered Tony, with a nod at the open cargo bay door.

Claire rolled to her side and laid Andy gently on the deck. His face crumpled, working up to a cry. Claire quickly rolled onto her palms, tested her balance. Her right lower arm seemed to be the one she could most easily spare. She scooped Andy back up one-handed and held him under her torso.

Plastered against the planet-ward side of the cargo bay by the dreadful gravity, she began a three-handed crawl toward the door. Andy's weight pulled at her arm as though a strong spring were drawing him to the floor, and his head bobbed backwards at an alarming angle. Claire inched her palm up under his head to support it, painfully awkward for her arm.

Beside her, Tony too achieved a three-handed stance. With his free hand he jerked the cord to their pack of supplies. The pack, stuck to the downside surface as if by suction, didn't budge.

"Shit," Tony swore under his breath. He swarmed over the pack, gripped and lifted it, but it was too bulky to carry under his belly. "*Double*-shit."

"Can we give up yet?" Claire asked in a tiny voice, knowing the answer.

"*No!*" He grabbed the pack backwards over both shoulders with his upper hands and rocked forward violently. It came up and balanced precariously on his back. He kept his left upper hand on it to steady it and hopped forward on his right, his lower palms shuffling along under his hips. "I got it, go, go!"

The shuttle was parked in a cavernous hangar, a vast dim gulf of space roofed by girders. The girders behind the overhead lights would have been an excellent hiding place, if only one could swoop up there. But everything not rigidly fastened was doomed to fly to the one side of the room only, and stick there until forcibly removed. There was a lopsided fascination to it . . .

"Oh . . ." Claire hesitated. Leading from the hatch to the hangar floor was a kind of corrugated ramp. Clearly, it was designed to break down the dangerous fight with the omnipresent gravity into little manageable increments. "*Stairs.*" Claire paused, head down. Her blood seemed to pool dizzyingly in her face. She gulped.

"Don't *stop,*" Tony gasped pleadingly behind her, then gulped himself.

"Uh . . . uh . . ." In a moment of inspiration, Claire turned around and began to back down, her free lower palm slapping the metal treads with each hop. It was still uncomfortable, but at least possible. Tony followed.

"Where now?" Claire panted when they reached the bottom.

Tony pointed with his chin. "Hide in that jumble of equipment over there, for now. We daren't get too far from the shuttles."

They scuttled along over the downside surface of the hangar. Claire's hands quickly became smudged with oil and dirt, a psychological irritation as fierce as an unscratchable itch; she felt

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she might gladly risk death for a chance to wash them. Claire remembered watching beads of condensed humidity creeping by capillarity across surfaces in the Habitat, until she'd smeared them to oblivion with her dry-rag, just as she and Tony crept now.

As they reached the area where some pieces of heavy equipment were parked, a loader rolled into the hangar and a dozen coveralled men and women jumped off it and began swarming over the shuttle, organized confusion. Claire was glad for their noise, for Andy was still emitting an occasional whimper. Fearfully, she watched the maintenance crew through the metal arms of the machinery. How late was too late to surrender?

Leo, half suited-up in the equipment locker, glanced up anxiously as Pramod swooped across the room to fetch up gracefully beside him.

'Did you find Tony?'' Leo asked. ''As gang foreman, he's supposed to be leading this parade. I'm only supposed to be watching.''

Pramod shook his head. ''He's not in any of the usual places, sir.''

Leo hissed under his breath, not quite swearing. ''He should've answered his page by now. . . .'' He drifted to the plexiport.

Outside in the vacuum, a small pusher was just depositing the last of the sections for the shell of the new hydroponics bay in their carefully arranged constellation. It was to be built before the operations' vice president's eyes by the quaddies. So much for Leo's faint hope that screw-ups and delays in other departments might cover those in his

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own. It was time for his welding crew to make its debut.

"*All right, Pramod, get suited up.* You'll take over Tony's position, and Bobbi from Gang B will take yours." Leo hurried on before the startlement in Pramod's eyes could turn to stage fright. "It's nothing you haven't practiced a dozen times. And if you have the least doubts about the quality or safety of any procedure, I'll be right there. Reality first—you people are going to be living in the structure you build today long after Vice President Apmad and her traveling circus are gone. I guarantee she'll have more respect for a job done right, however slowly, than for a piece of slap-dash fakery."

For God's sake make it look smooth, Van Atta had instructed Leo urgently, earlier. *Keep to the schedule, no matter what—we'll fix the problems later, after she's gone. We're supposed to be making these chimps seem cost-effective.*

"You don't have to try and seem to be anything but what you are," Leo told Pramod. "You *are* efficient—and you are good. Instructing you all has been one of the great unexpected pleasures of my career. Be off, now, I'll catch up with you shortly."

Pramod sped away to find Bobbi. Leo frowned briefly to himself, and floated up the length of the locker room to the comconsole terminal at the end.

He keyed in his ID. "Page," he instructed it. "Dr. Sondra Yei." At the same moment a message square in the corner of the vid began to blink with his own name, and a number. "Cancel that instruction."

He punched up the number and raised his brows in surprise as Dr. Yei's face appeared on his vid. "Sondra! I was just about to call you. Do you know where Claire is?"

"How odd. I was calling to ask you if you knew where I could reach Tony."

"Oh?" said Leo, in a voice suddenly drained to neutrality. "Why?"

"Because I can't find her anywhere, and I thought Tony might know where she is. She's supposed to be giving a demonstration of child care techniques in free fall to Vice President Apmad after lunch."

"Is, um," Leo swallowed, "Andy at the crèche, or with Claire, do you know?"

"With Claire, of course."

"Ah."

"Leo . . ." Dr. Yei's attention sharpened, her lips pursed. "Do you know something I don't?"

"Ah . . ." he eyed her. "I know Tony has been unusually inattentive at work for the last week. I might even say—depressed, except that's supposed to be your department, eh? Not his usual cheerful self, anyway." A knot of unease, tightening in Leo's stomach, gave his tongue an unaccustomed edge. "You, ah, got any concerns that you may have forgotten to share with me, lady?"

Her lips thinned, but she ignored the bait. "Schedules have been moved up in all departments, you know. Claire received her new reproduction assignment. It didn't include Tony."

"Reproduction assignment? You mean, having a baby?" Leo could feel his face flushing. Somewhere within him, a long-controlled steam pressure began to build. "Do you hide what

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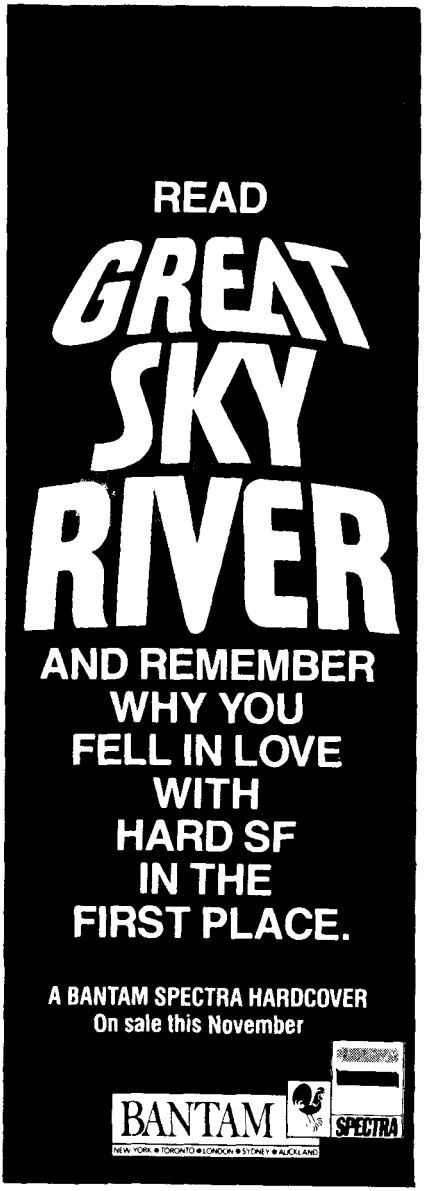
you're really doing from yourselves with those weasel-words, too? And here I thought the propaganda was just for us peons." Yei started to speak, but Leo overrode her, bursting out, "Good God! Were you born inhuman, or did you grow so by degrees—M.S., M.D., Ph.D. . . ."

Yei's face darkened, her accent grew clipped. "An engineer, with romance in his soul? Now I've seen everything. Don't get carried away with your scenario, Mr. Graf. Tony and Claire were assigned to each other in the first place by the exact same system, and if *certain people* had been willing to abide by my original timetable, this problem could have been avoided. I fail to see the point of paying for an expert and then blithely ignoring her advice, really I do. Engineers. . . !"

Ah, hell, she's suffering from as bad a case of Van Atta as I am, Leo realized. The insight blunted his momentum, without bleeding off his internal pressure.

"—I didn't invent the Cay Project, and if I were running it I'd do it differently, but I have to play the hand I'm dealt, Mr. Graf. Blast—" she controlled herself, almost visibly wrenching the conversation back on its original track. "I've got to find her soon, or I'll have no choice but to let Van Atta start the show ass-backwards. Leo, it's absolutely essential that Vice President Apmad get the crèche tour first, before she has time to start forming any—do you have any idea at all where those kids may be?"

Leo shook his head; an inspiration turned the truthful gesture to a lie even before he'd finished it. "But will you



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give me a call if you find them before I do?" he pleaded, his humble tone offering truce.

Yei's stiffness wilted a bit. "Yes, certainly." She shrugged wryly, a silent apology, and broke off.

Leo swung back to his locker, peeled out of his work suit, donned coveralls, and hastened off to track down his inspiration before Dr. Yei duplicated it independently. He was certain she would, and shortly, too.

Silver checked the work schedule on her vid display. Bell peppers. She floated across the hydroponics bay to the seed locker, found the correct labeled drawer, and withdrew a precounted paper packet. She gave the packet an absent shake, and the dried seeds made a pleasing rattle.

She collected a plastic germination box, tore open the packet, and coaxed the little pale seeds into the container, where they bounced about cheerfully. To the hydration spigot next. She thrust the water tube through the rubber doughnut seal on the side of the germination box and administered a measured squirt, and gave the box an extra shake to break up the shimmering globule of liquid that formed. Shoving the germination box into its slot in the incubation rack, she set it for the optimum temperature for peppers, bell, hybrid phototropic non-gravitational axial differentiating clone 297-X-P, and sighed.

The light from the filtered windows plucked insistently at her attention, and she paused for the fourth or fifth time this shift to weave among the grow tubes and stare out at the portion of Rodeo this bay's angle of view allowed her to see. Somewhere down there, at the bottom of that well of air, Claire and Tony were crawling now—if they had not already surrendered—or managed to make it to another shuttle—or met some horrible catastrophe. . . . Silver's imagination, unbidden, supplied her with a string of sample catastrophes.

She tried to crowd them out with a firm mental picture of Tony and Claire and Andy successfully sneaking onto a shuttle bound for the Transfer Station, but the picture wavered into a scenario of Claire, attempting to jump some gap to the shuttle's hatchway (what gap? from where, for pity's sake?) forgetting that all such tangents were bent to parabolas by the gravitational force, and missing the target. Silver thought of the peculiar ways things moved in dense gravitational fields. The scream, chopped off by the splat on the concrete below—no, surely Claire would be holding Andy—the *double* splat on the concrete below. . . . Silver kneaded her forehead with the heels of her upper hands, as if she might physically press the grisly vision back out of her brain. Claire had seen the same vids of life downside, surely she'd remember.

The hiss of the airseal doors twitched Silver back to present reality. Better look busy—what was she supposed to be doing next? Oh, yes, cleaning used grow tubes, in preparation for their placement day after tomorrow in the new bay they were building to show off everybody's skills to the Ops VP. Damn the Ops VP. But for her, there'd be a chance Tony and Claire might go unmissed for two shifts, even three. Now . . .

Her heart shrank, as she saw who had

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entered the hydroponics bay. Now, indeed.

Ordinarily, Silver would have been glad to see Leo. He seemed a big, clean man—no, not large, but solid somehow, full of a prosaic calmness that spilled over in the very scent of him, reminiscent of downsider things Silver had chanced to handle, wood and leather and certain dried herbs. In the light of his slow smile, ghastly scenarios thinned to mist. She might yet be glad to talk to Leo . . .

He was not smiling now. "Silver. . . ? You in here?"

For a wild moment Silver considered trying to hide among the grow tubes, but the foliage rustled as she turned, giving away her position. She peeked over the leaves. "Uh . . . hi, Leo."

"Have you seen Tony or Claire lately?" Trust Leo to be direct. *Call me Leo*, he'd told her the first time she'd "Mr. Graf'd" him. *It's shorter*. He drifted over to the grow tubes; they regarded each other across a barrier of bush beans.

"I haven't seen anybody but my supervisor all shift," said Silver, momentarily relieved to be able to give a perfectly honest answer.

"When did you last see either one of them?"

"Oh—last shift, I guess," Silver tossed her head airily.

"Where?"

"Uh . . . around." She giggled vacuously. Mr. Van Atta might have thrown up his hands in disgust at this point, and abandoned any attempt to wring sense from so empty a head as hers.

Leo frowned at her thoughtfully. "You know, one of the charms of you kids is the literal precision with which you answer any question."

The comment hung in air expectantly, as Leo did. The picture of Tony, Claire, and Andy scooting across the shuttle loading bay flashed in Silver's mind with hallucinatory clarity. She groped in memory for their prior meeting, where the final plans had been laid, to offer up as a half-truth. "We had the mid-shift meal together last shift at Nutrition Station 7."

Leo's lips quirked. "I see." He tilted his head, studying her as if she were some puzzle, such as two metallurgically incompatible surfaces he had to figure out how to join.

"You know, I just heard about Claire's new, ah, reproduction assignment. I'd wondered what was bothering Tony the last few weeks. He was pretty broken up about it, eh? Pretty . . . distraught."

"They'd had plans," Silver began, caught herself, shrugged casually. "I don't know. *I'd* be glad to get any reproduction assignment. There's no pleasing some people."

Leo's face grew stern. "Silver—just how distraught were they? Kids often mistake a temporary problem for the end of the world, and they have no sense of the fullness of time. Makes 'em excitable. Think they might have been upset enough to do something . . . desperate?"

"Desperate?" Silver smiled rather desperately herself.

"Like a suicide pact or something?"

"Oh, no!" said Silver, shocked. "Oh, they'd never do anything like that."

Did relief flash for a moment in Leo's

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brown eyes? No, his face puckered in intensified concern.

"That's just what I'm afraid they might have done. Tony didn't show up for his work shift, and that's unheard of; Andy's gone too. They can't be found. If they felt so desperate —trapped—what could be easier than slipping out an airlock? A flash of cold, a moment's pain, and then—escape forever." His single pair of hands clasped earnestly. "And it's all my fault. I should have been more perceptive—said something. . . ." he paused, looking at her hopefully.

"Oh, no, it was nothing like that!" Silver, horrified, hastened to dissuade him. "How awful for you to think that. Look . . ." she glanced around the hydroponics bay, lowered her voice. "Look, I shouldn't tell you this, but I can't let you go around thinking —thinking those fearful things." She had his entire attention, grave and intent. How much dare she tell him? Some suitably edited reassurance . . . "Tony and Claire—"

"Silver!" Dr. Yei's voice rang out as the airseal doors slid open. Echoed by Van Atta's bellow, "Silver, what do you know about all this?"

"Aw, shit," Leo snarled under his breath. His piously clasped hands clenched to fists of frustration.

Silver drew back in understanding and indignation. "You—!" And yet she almost laughed; Leo, so subtle and tricksy? She'd underestimated him. Did they both wear masks before the world, then? If so, what unknown territories did his bland face conceal?

"Please, Silver, before they get here —I can't help you if . . ."

It was too late. Van Atta and Yei tumbled into the room.

"Silver, do you know where Tony and Claire have gone?" Dr. Yei demanded breathlessly. Leo drew back into reserved silence, appearing to take an interest in the fine structure of the white bean blossoms.

"Of course she knows," Van Atta snapped, before Silver could reply. "Those girls are in each others' pockets, I tell you—"

"Oh, I *know*," Yei muttered.

Van Atta turned sternly to Silver. "Cough it up, Silver, if you know what's good for you."

Silver's lips closed, firmed into a line; her chin lifted.

Dr. Yei rolled her eyes at her superior's back. "Now, Silver," she began placatingly, "this isn't a good time for games. If, as we suspect, Tony and Claire have tried to leave the Habitat, they could be in very serious trouble by now, even physical danger. I'm pleased that you feel you should be loyal to your friends, but I beg you, make it a responsible loyalty—friends don't let friends get hurt."

Silver's eyes puddled in doubt; her lips parted, inhaling for speech.

"Damn it," cried Van Atta, "I don't have time to stand around sweet-talking this little cunt. That snake-eyed bitch that runs Ops is waiting up there *right now* for the show to go on. She's starting to ask questions, and if she doesn't get the answers pronto she'll come looking for 'em herself. That one plays hardball. Of all the times to pick for this outbreak of idiocy, this has gotta be the worst possible. It's got to be deliberate. Nothing this fouled up could be by chance."

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His red-faced rage was having its usual effect on Silver; her belly trembled, her vision blurred with unshed tears. She had once felt she would give him anything, do anything at all, if only he would calm down and smile and joke again.

But not this time. Her initial awed infatuation with him had been emptied out of her, bit by bit, and it startled her to realize how little was left. A hollowed shell could be rigid and strong . . . "You," she whispered, "can't *make* me say anything."

"Just as I thought," snarled Van Atta. "Where's your *total socialization* now, Dr. Yei?"

"If you would," said Dr. Yei through her teeth, "kindly refrain from teaching my subjects anti-social behavior, you wouldn't have to deal with its consequences."

"I don't know what you're whining about. I'm an executive. It's my job to be hard-assed. That's why GalacTech put me in charge of this orbiting money-sink. Behavior control is your department's responsibility, Yei, or so you claimed. So do your job."

"Behavior *shaping*," Dr. Yei corrected frostily.

"What the hell's the use of that if it breaks down the minute the going gets tough? I want something that works all the time. If you were an engineer you'd never get past the reliability specs. Isn't that right, Leo?"

Leo snapped off a bean leaf stem, smiled blandly. His eyes glittered. He must have been chewing on his reply; at any rate, he swallowed *something*.

Silver grasped at a simple plan. So simple, surely she could carry it out. All she had to do was nothing. Do nothing, say nothing; eventually, the crisis must pass. They could not physically damage her, after all, she was valuable GalacTech property. The rest was only noise. She shrank into the safety of thing-ness, and stony silence.

The silence grew thick as cold oil. She nearly choked on it.

"So," hissed Van Atta to her, "that's the way you want to play it. Very well. Your choice." He turned to Yei. "You got something in the Infirmary like fast-penta, Doctor?"

Yei's lips rippled. "Fast-penta is only legal for police departments, Mr. Van Atta."

"Don't they need a court order to use it, too?" inquired Leo, not looking up from the bean leaf he twirled between his fingers.

"On citizens, Leo. That," Van Atta pointed at Silver, "is not a citizen. What about it, Doctor?"

"To answer your question, *Mr.* Van Atta, no, our Infirmary does *not* stock illegal drugs!"

"I didn't say fast-penta, I said something *like* it," said Van Atta irritably. "Some sort of anesthetic or something, to do in a pinch."

"Are we in a pinch?" asked Leo in a mild tone, still twirling his leaf; it was getting frayed. "Pramod is substituting for Tony, surely one of the other girls with babies can take over for Claire. Why should the Ops VP know the difference?"

"If we end up having to scrape two of our workers off the pavement downside—"

Silver winced at this echo of her own ghastly scenario.

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"—or find them floating freeze-dried outside somewhere up here, it'll be damned hard to conceal from her. You haven't met the woman, Leo. She has a nose for trouble like a weasel."

"Mm," said Leo.

Van Atta turned back to Yei. "What about it, Doctor? Or would you rather wait until someone calls us up asking what to do with the bodies?"

"IV Thalizine-5 is a bit like fast-penta," muttered Dr. Yei reluctantly, "in certain doses. It will make her sick for a day, though."

"That's her choice." He wheeled on Silver. "Your last chance, Silver. I've had it. I despise disloyalty. Where did they go? Tell me, or it's the needle for you, right now."

She was driven from thing-ness at last to a more painful, active human courage. "If you do that to me," Silver whispered in desperate dignity, "we're through."

Van Atta recoiled in sputtering outrage. "Through? You and your little friends conspire to sabotage my career in front of the company brass and you tell *me* we're through? You're damn right we're through!"

"Company Security, Shuttleport Three, Captain Bannerji speaking," George Bannerji recited into his com-console. "May I help you?"

"You in charge here?" the well-dressed man in his vid began abruptly. He was clearly laboring under strong emotion, breathing rapidly. A muscle jumped in his clamped jaw.

Bannerji took his feet off his desk and leaned forward. "Yes, sir?"

"I'm Bruce Van Atta, Head of Project at the Habitat. Check my voiceprint, or whatever it is you do."

Bannerji sat up straight, tapped out the check-code; the word "cleared" flashed for a moment across Van Atta's face. Bannerji sat up straighter still. "Yes, sir, go ahead."

Van Atta paused as if groping for words, speaking slowly despite the jostling urgency of thought apparent in his tense face. "We have a little problem here, Captain."

Red lights and sirens went off in Bannerji's head. He could recognize an ass-covering understatement when he heard one. "Oh?"

"Three of our—experimental subjects have escaped the Habitat. We interrogated their coconspirator, and we believe they stowed away on shuttle flight B119, and are now loose somewhere in Shuttleport Three. It is of the utmost urgency that they be captured and returned to us as quickly as possible."

Bannerji's eyes widened. Information about the Habitat was under a tight company security lid, but no one could work on Rodeo for long without learning that some kind of genetic experiments on humans were taking place up there, in careful isolation. It usually took a little longer for new employees to figure out that the more exotic monster stories told by the old hands were a form of hazing, practiced upon their credulity. Bannerji had transferred in to Rodeo about a month ago.

The Project Chief's words rang through Bannerji's head. *Escaped. Captured.* Criminals escaped. Dangerous zoo animals escaped, when their keepers screwed up, then some poor shmuck of

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a cop got the job of capturing them. Occasionally, horrifying biological weapons escaped. What the hell was he dealing with?

"How will we recognize them, sir? Do they," Bannerji swallowed, "look like human beings?"

"No." Van Atta evidently read the dismay in Bannerji's face, for he snorted ironically. "You'll have no trouble recognizing them, I assure you, Captain. And when you do find them, call me at once on my private code. I don't want this going out over broadcast channels. For God's sake keep it quiet, understand?"

Bannerji envisioned public panic. "Yes, sir. I understand completely."

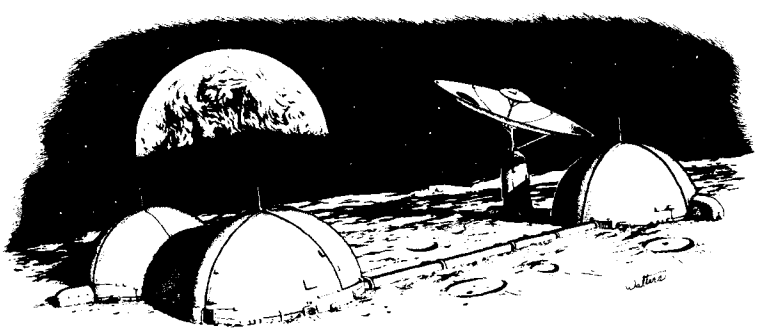
His own panic was a private matter. He wouldn't be collecting the fat salary he did if Security was expected to be all extended coffee breaks and pleasant evening strolls around perfectly deserted property. He'd always known the day would come when he'd have to earn his pay.

Van Atta broke off with a grim nod. Bannerji put in a call on the comconsole for his subordinate, and placed pages for both his off-duty men as well. Something that had the executive hierarchy pouring sweat was nothing for a newly-promoted Security grunt to take chances with.

He unlocked the weapons cabinet and signed out stunners and holsters for himself and his team. He weighed a stunner thoughtfully in his palm. It was such a light little diddly thing, almost a toy; GalacTech risked no lawsuits over stray shots from weapons like these.

Bannerji stood a moment, then turned to his own desk and keyed open the drawer with his personal palm-lock. The unregistered pistol nestled in its own locked box, its shoulder holster coiled around it like a sleeping snake. By the time Bannerji had buckled it on and shrugged his uniform jacket back over it, he was feeling much better. He turned decisively to greet his patrolmen reporting for duty. ■

CONTINUED IN NEXT ISSUE



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Dr. John Gribbin

THE LOST YEARS OF COSMOLOGY

There are those who think of science as "cut and dried"—which merely proves they don't understand how science is really done. Consider, for example, the apparently simple question of assigning credit. . . .

THE BIG BANG is the centerpiece of modern cosmology—one of the greatest achievements of science. The idea that the Universe began in a hot, superdense state some 15 billion years ago, and has been expanding ever since, is now the ultimate creation myth. But it only achieved this exalted status in the 1960s, a full twenty years after the theory was first aired, and, more to the point, a full twenty years after the observers could have, and should have, proved it to be a valid description of the Universe. During those lost years, it seems with hindsight, the astronomers simply could not bring themselves to believe that the equations they chalked on their blackboards really did represent reality—to them, it was just a mathematical game. The lost years cost at least one man dear. George Gamow, the father of the Big Bang theory, was dead by the time it became so well established that the prizes started being handed out. Had it not been for the lost years, he would certainly have won the Nobel.

Gamow was a larger than life character with a boundless imagination which took him from nuclear physics to cosmology and then into the world of molecular biology. He made significant contributions in all three areas of science—*the* three key areas of twentieth century science—and found time along the way to write books for the layman, carry out elaborate practical jokes on his colleagues, and generally to illuminate the world of science in the middle decades of the century. He achieved all this despite being indifferent about such minor details of life as spelling or dates, and being hopeless at working out simple arithmetic. Born in the Ukraine, at Odessa, in 1904, after he moved per-

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manently to America in the mid-1930s Gamow always signed his letters to his friends "Geo.," an abbreviation which he was unshakably convinced was pronounced "Joe"; so "Joe" he was, to the very large number of those friends, until his death in 1968.

Having lived through the turmoil of revolution and civil war in Russia, in 1922 Gamow enrolled at Novorossysky University, but soon transferred to the University of Leningrad, where he stayed until 1928, gaining a PhD. Once qualified, he traveled to the University of Göttingen, then to the Institute of Theoretical Physics in Copenhagen, then to the Cavendish laboratory in Cambridge, and then back to Copenhagen. The three scientific centers he visited in the years from 1928 to 1931 were at the heart of the revolution in physics then taking place, the discovery of quantum physics and the beginnings of the application of the new theory to an understanding of atoms. Gamow learned his quantum physics from the pioneers in the subject. And during his visit to Göttingen he made the first of his major contributions to science, applying quantum theory to explain how an alpha particle could escape from an atomic nucleus.

Each of these alpha particles, it is now known, consists of two protons and two neutrons, held together by the strong nuclear force which overcomes the electric force of repulsion between the protons. They are, indeed, identical to helium nuclei, in effect helium atoms from which the two electrons (all that the atom possesses) have been removed. When an alpha particle is inside the nucleus of a very heavy atom, it is held in by the strong nuclear force. If an alpha particle is just outside the nucleus, however, the electric repulsion force dominates, because the nuclear force has only a very short range, and so the particle is ejected. Extending the idea of a stable state as being at the bottom of a valley, in energy terms, for the alpha particle the nucleus is like the interior of an extinct volcano. Deep in the heart of the volcano, it is energetically stable; but if it were just a little bit outside the volcano it would be on the steeply sloping sides of the mountain, and would rapidly roll away. Gamow showed how an alpha particle could get over the hill, as it were, from just inside the nucleus to just outside—and his explanation of alpha decay was the first successful application of quantum theory to the nucleus.

In 1931, Gamow was called back to the USSR, where he was appointed Master of Research at the Academy of Sciences in Leningrad, and Professor of Physics at Leningrad University. But his ebullient nature and independence of mind hardly suited him to a happy life under Stalin's regime in the 1930s, and when he was allowed to attend a scientific conference in Brussels in 1933 he seized the opportunity to stay away, moving to George Washington University in Washington, D.C., where he was Professor of Physics from 1934 to 1956, and then to the University of Colorado, in Boulder, where he stayed until his death.

Gamow's interest in how things got *out* of atomic nuclei led him to wonder about the possibility of particles getting *in*, climbing the hill from outside and

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dropping into the region where the strong nuclear force dominates. He was involved in pioneering calculations which showed that if protons could be fired into atoms with energies of a few hundred kilovolts then they would trigger the kind of nuclear reactions that cause nuclear fission and alpha decay. John Cockroft and Ernest Walton, working at the Cavendish Lab, did just that in 1932, creating the world's first particle accelerator, using a high voltage electric field to accelerate protons and smash them into atoms, and triggering reactions in exactly the way Gamow had predicted. This was the first step along the road that led eventually to the atomic bomb, and to the first nuclear power stations, deriving energy from the fission process. But the idea of sticking protons onto existing nuclei by, in effect, pushing them together hard enough to overcome the long-range electric repulsive forces and allow the short-range nuclear forces to dominate, also led Gamow to the Big Bang.

The neutron is the key component of Gamow's universe. As long as a neutron is inside a stable atomic nucleus, it retains its identity as a neutron. But left to their own devices individual neutrons themselves decay, each of them breaking down into one proton and one electron. This decay occurs quite rapidly, with a half life of about 13 minutes.* So, if you started out with a very dense universe full of neutrons, a kind of neutron gas, you would very quickly have a supply of protons and electrons as well, with precisely enough particles of each kind around (the same number of electrons as protons) for every stable atom that might be formed to have an equal number of protons and electrons and leave no excess electric charge left over.

Gamow's idea immediately supplied hydrogen for the universe. Each hydrogen atom consists simply of one proton with one electron held in its neighborhood by the electric force of attraction between opposite charges. Allow a neutron to decay, and there you are with a bare hydrogen nucleus and a handy electron, all ready to make an atom. But where do the rest of the atoms, those corresponding to helium and the heavier elements, come from?

During the 1940s, Gamow was joined at George Washington University by Ralph Alpher, a graduate student to whom he assigned the task of working out the details of how more complex nuclei might have been built up from hydrogen (a process known as nucleosynthesis) in the Big Bang. The model they developed depended on collisions between the particles in the cosmic soup of dense material in the first few minutes of the life of the universe. The calculations showed that it would be relatively easy for a proton (hydrogen nucleus) and a neutron to collide strongly

*The half life is the time it takes for half of the particles in a sample to decay. If you start with 100 neutrons, after 13 minutes there will be 50 left, after 26 minutes there will be 25 left, after 39 minutes a dozen, and so on. This kind of statistical behavior, in which the fate of an individual particle cannot be predicted (there is no way to tell *which* of the original neutrons will decay in the first 13 minutes, or any subsequent period) but the overall behavior of a large group (it should really, of course, be far more than 100) is completely predictable, is one of the most striking aspects of quantum physics. It applies to all radioactive decays, and to other processes, not just to the decay of the neutron.

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enough to overcome electrostatic repulsion and stick together, to form a nucleus of deuterium, also known as heavy hydrogen. Another collision with a neutron would produce a nucleus of tritium, containing one proton and two neutrons. But tritium is unstable, so that one of its neutrons soon spits out an electron and becomes a proton. The nucleus has now evolved into one that corresponds to an isotope of helium, containing two protons and one neutron, and called, for obvious reasons, helium-3. All it needs now is for another neutron to stick to the growing nucleus to make an alpha particle, the nucleus of a helium-4 atom. So far, so good. There was no need to worry about the electrons, since once the nuclei were manufactured they could easily pick up the electrons they needed from the swarm of particles in the primeval soup. But at that point the model ran into a snag.

The helium-4 nucleus, the alpha particle, is a particularly stable state. It is very disinclined either to break up into smaller components, or to accept additional components and grow into something more complex. Worse, there is no naturally occurring element which has a nucleus containing five particles, and when such a nucleus is made artificially in the lab by bombarding helium-4 with neutrons it immediately breaks down to helium-4 again. In order to get around this difficulty, Gamow and Alpher had to speculate that a single helium-4 nucleus might occasionally be struck *simultaneously* by two particles and capture them both to form a nucleus containing six particles. Even if this happens, the same problem arises for the nucleus containing eight particles, which very rapidly breaks down into two alpha particles.* And with the universe rapidly thinning out as it expands away from the superdense state of the Big Bang, by the time you have made the helium the chance of a double collision of this kind is small, and rapidly getting smaller. In the 1940s, although the prospect of getting over these gaps by the capture of two particles at once seemed unlikely, there was just enough ignorance about conditions in the early Universe, and about the rates at which such nuclear reactions might occur, to allow Gamow and Alpher to get away with the idea, as a working hypothesis. After all, as Gamow used to tell anyone who was interested, the theory explained where all of the hydrogen and all of the helium in the Universe came from, and that accounted for more than 99 percent of the matter visible in stars and galaxies. Even if the theory didn't properly explain the synthesis of the heavy elements (to an astronomer, anything except hydrogen and helium is a "heavy" element) they represented less than one percent of the problem.

The detailed calculations of how nuclei can capture neutrons or protons (the numbers that come out of the calculations are called capture cross sections) formed the basis of Alpher's Ph.D. thesis, submitted in 1948. It clearly de-

*The image of a smoothly sloping valley with iron-56 at the bottom is, of course, an oversimplification. The helium-4 nucleus, to extend the analogy, sits in its own hole in the ground on the side of the valley, from which it cannot easily be dislodged; the nucleus with eight particles might be thought of as balanced on top of a molehill on the valley side (a very sharply pointed molehill!) from which it topples at the slightest provocation.

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served a wider audience, however, and Alpher and Gamow wrote up a paper for submission to the *Physical Review*. At this point, Gamow's sense of fun overcame him, and he perpetrated his most famous scientific joke. "It seemed unfair to the Greek alphabet," he wrote later,† "to have the article signed by Alpher and Gamow only, and so the name of Dr. Hans A. Bethe *(in absentia)* was inserted in preparing the manuscript for print. Dr. Bethe, who received a copy of the manuscript, did not object." So the classic paper in which the modern version of the Big Bang model first saw the light of day appeared, on 1 April 1948 (a coincidence which delighted Gamow) under the names Alpher, Bethe and Gamow. To this day, it is known as the "alpha, beta, gamma" paper, a suitable reflection of the fact that it deals with the beginning of things, and also of the importance of particle physics to cosmology (alpha particles we have already met; beta particle is another name for electron, and gamma ray is the name for an intense pulse of electromagnetic radiation, an energetic photon).

This early version of the Big Bang appeared in the same year, 1948, that Fred Hoyle, Tommy Gold and Hermann Bondi came up with their idea of an expanding steady state universe. Right through the 1950s and into the 1960s the two rival ideas stirred debate among the experts, with Hoyle as the leading steady stater and Gamow the leading big banger in friendly rivalry. Ironically, it was to be Hoyle who would show how to resolve the greatest difficulty with Gamow's universe, finding a way to make the heavy elements inside stars, once the initial job of cooking up helium in the Big Bang had been carried out. But there is an even greater irony in the story, involving one of the most significant missed opportunities in the history of science, and emphasizing the way even cosmologists failed to take their equations seriously at that time.

In those days, cosmology was very much a game. Rival models were developed and tested against one another almost as a kind of abstract mathematical duel, with little thought that one of these models might, in fact, be a correct mathematical description of our own Universe. Even Gamow, who loved his theory of the universe as if it were his own son, fell into this trap.

The conditions needed to make even helium in the Big Bang (never mind the heavy elements for now) include both very high density *and* very high temperature. Although you might imagine a cold soup of neutrons expanding away from a state of very high density, quite simple calculations show that such a cold neutron soup is very rapidly converted almost entirely into helium. It is only in a hot Big Bang that most of the matter stays as hydrogen, and curiously but just one of those things, it doesn't make much difference what the exact density of the model universe is a few seconds after the moment of creation. Provided the universe is hot, you always end up with about a third of the matter being turned into helium, with the rest staying as hydrogen until it is reprocessed in stars as the universe evolves.

Most of the hydrogen is prevented from being cooked into helium while

†*The Creation of the Universe*, page 65.

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the universe is very dense by the presence of a great deal of energetic radiation. This electromagnetic radiation can be thought of in terms of particles, called photons. Alpher and another young researcher, Robert Herman, used the fact that about a third of the Universe is helium and the rest hydrogen to calculate how many photons there must be in the Universe; it comes out at a staggering billion photons for every nuclear particle (that is, for every proton or neutron). Radiation—photons—is a form of energy, and the density of the radiation (the amount of energy in a certain volume of space) can be expressed in terms of temperature. Winding back the Friedman equations to the early seconds of the Universe, Alpher and Herman showed that there must have been a time when the energy density of the radiation was greater than the energy density of the matter, given in terms of Einstein's famous equation $E = mc^2$. The Gamow universe was born out of a fireball of radiation, quickly cooling as it expanded, and only becoming dominated by matter after it had expanded, and cooled, by a critical amount. But the radiation would still be there, filling the entire universe but getting thinner, cooler and weaker as time went by. In 1948, Alpher and Herman published a paper in which they calculated that the temperature of this leftover radiation today must be about five degrees absolute, 5 K*.

In his popular book *The Creation of the Universe*, published in 1952, Gamow gives a slightly different estimate for the temperature of the Universe today (and also bemoans Herman's stubborn refusal to change his name to Delter). He derives an equation which says that the temperature is equal to 1.5×10^{10}, divided by the square root of the age of the Universe in seconds. This gave him an estimate of about 50 K. At other times in the early 1950s, Gamow and his colleagues came up with other figures in the range from 5 K to 50 K, depending on what assumptions they made about the state of the early Universe and its age. Today, particle physicists calculate that a more accurate version of Gamow's equation simply sets the temperature now as 10^{10} divided by the square root of its age in seconds, and in addition the estimates for the age have increased, all of which reduces the top estimate for the temperature of the Universe at present. This equation is only an approximate relation, and there are better ways to calculate the temperature of the Universe at any epoch. But it is a useful rule of thumb, which tells us, for instance, that one second after the moment of creation the temperature was 10 billion degrees, that after 100 seconds it had already cooled to one billion degrees, that after 100 seconds it had already cooled to one billion degrees, and that after one hour it was down to 170 million degrees. For comparison, the temperature at the heart of our Sun is calculated to be about 15 million degrees.

Here was a clear prediction made by the hot Big Bang theory. It said that the Universe ought to be filled with a sea

*The zero of the Kelvin scale of temperature is −273 °C, to the nearest whole number. It is the absolute zero of temperature at which all particles are in their lowest energy levels, called zero-point states; there can be nothing colder.

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of radiation with an energy equivalent to a temperature of a few K. Such radiation would be detectable at radio wavelengths, and radio astronomy was just getting started in the early 1950s. But no radio astronomer picked up the idea and went out to test it, while Gamow and his team went their own ways into other areas of research (Gamow himself becoming fascinated by the problem of cracking the genetic code of DNA), and never went out on the campaign trail to drum up interest in the idea and encourage, or force, the radio astronomers into appropriate action. What went wrong? The best explanation is the one put forward by physicist Steven Weinberg in his book *The First Three Minutes*. "It was," he said, "extraordinarily difficult for physicists to take seriously *any* theory of the early universe" in those days. "Our mistake is not that we take our theories too seriously, but that we do not take them seriously enough. It is always hard to realize that these numbers and equations that we play with at our desks have something to do with the real world."

By 1956, when Gamow went on his way to Colorado and the team disbanded, the early version of the hot Big Bang model had posed two questions, the answers to which were to provide the basis for further developments. One of those questions was widely recognized, and great strides towards answering it were made in the late 1950s and early 1960s. It was the question of where the heavy elements come from, if they are not manufactured in the Big Bang. The other question was unnoticed and remained buried in the scientific literature until it was answered by accident in 1964. It was the question of the background temperature of the Universe today. The combination of these two answers—each of which led to the award of a Nobel Prize—with Gamow's universe initiated the modern era in cosmology.

The idea of taking the temperature of the Universe and using the measurement to find out more about the Big Bang in which the Universe was born may have been too farfetched for physicists and astronomers to take seriously in the 1950s. But that doesn't mean the idea was totally ignored, and more than one astronomer has looked back ruefully to that decade and metaphorically kicked himself for failing to follow the idea through to its logical conclusion. Indeed, Gamow, Alpher and Herman must have shared these feelings—not least since some astronomical observations which clearly implied a background temperature off the Universe of about 3 K had already been carried out in the 1930s, and were certainly known to Gamow and his colleagues in the 1950s.

These observations, like so much of our information from space, depend on spectroscopy. In the 1930s, astronomers began to identify, for the first time, spectral features corresponding to the presence of molecules in interstellar space. Starlight carries with it the spectral signature of the atoms (or more accurately ions, atoms with some electrons stripped off) present in the atmosphere of the star. The characteristic lines stand out as either bright emission lines (radiating energy) or dark absorption line

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(absorbing energy from the star below) in the electromagnetic spectrum. The strength of these lines, and the extent of the ionization they reveal, enables astronomers to deduce the temperature of a distant star, as well as to determine its composition. But there are also lines in some spectra which correspond to compounds that could not possibly be stable at the temperature at the surface of a star. One of the earliest of these to be identified is cyanogen, CN, a stable pairing of one carbon atom and one nitrogen atom to produce what is known as a radical. Such compounds occur not in the stars themselves, where the heat would soon break them into their component atoms, but in cool clouds of gas and dust between the stars. Their presence is revealed by the dark lines they impose on the light from distant stars shining through the cool clouds.

Just as observations of stellar spectra reveal the temperatures of the stars, so observations of these absorption spectra can reveal the temperature of the clouds of interstellar material. In 1940, W. S. Adams, at Mount Wilson, observed interstellar spectral lines corresponding to an energetic state of cyanogen, and Andrew McKellar, of the Dominion Astrophysical Observatory in Canada, interpreted those observations as indicating a temperature for the interstellar clouds of about 2.3 K. By 1950, the result was enshrined in a standard textbook on spectroscopy,* and was very well known to astronomers, including Gamow. But nobody thought of interpreting the temperature of the coldest clouds of material found in space as "the temperature of the Universe." One of the nearest misses came in 1956, when Fred Hoyle and George Gamow were cruising around La Jolla, in southern California, in a brand new white Cadillac convertible.

Hoyle recounted the tale in an article in *New Scientist* published in 1981. He was visiting Willy Fowler and his colleagues at CalTech that summer, and Gamow called them from La Jolla to invite Fowler, Hoyle and the Burbidges down for a visit. Gamow was in La Jolla because he was spending two months as a consultant with General Dynamics, a job which was very lucrative (the two months' consultation fee paid for the white Cadillac convertible) and apparently required little real work, but for which Gamow was obliged to stay in La Jolla somewhere (even on the beach) to be on call immediately if his services were required. So the B^{2}FH team made their way, not too reluctantly, south to La Jolla. At that time, Gamow's estimates for the temperature of the Universe today were in the range from about 5 K to a few tens of K; Hoyle, as a steady stater, thought there should be no background radiation at all. So they both missed the truth that lay under their noses, Hoyle takes up the story:

> There were times when George and I would go off for a discussion by ourselves. I recall George driving me around in the white Cadillac, explaining his conviction that the Universe must have a microwave background, and I recall my telling George that it was impossible for the Universe to have a microwave

*G. Herzberg, *Spectra of Diatomic Molecules*, second edition, Van Nostrand, Princeton, 1950.

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background with a temperature as high as he was claiming, because observations of the CH and CN radicals by Andrew McKellar had set an upper limit of 3 K for any such background. Whether it was the too-great comfort of the Cadillac, or because George wanted a temperature higher than 3 K whereas I wanted a temperature of zero K, we missed the chance. . . . For my sins, I missed it again in exactly the same way in a discussion with Bob Dicke at the twentieth Varenna summer school on relativity in 1961. In respect of the microwave background, I was evidently not "discovery prone". . . .

The Bob Dicke that Hoyle discussed the problem with in Varenna in 1961 deserves a special place in the hall of missed opportunities, for, quite apart from that conversation, he missed the chance to go down in history as "the man who took the temperature of the Universe" not once but *twice*—and on the second occasion he had forgotten about his own earlier work on the problem! Just a year younger than Hoyle, Dicke was born in St. Louis, Missouri, in 1916. He graduated from Princeton in the late 1930s, completed a PhD. at Rochester University in 1941, and worked on radar at MIT during the war, before joining the faculty at Princeton in 1946. He has stayed there ever since, to become Chairman of the Department of Physics and Albert Einstein Professor of Science. Dicke is nobody's fool. But he, too, could not see in the 1940s what now seems obvious, with hindsight.

During his time at MIT, Dicke developed an instrument for measuring very short wavelength radio radiation, in the microwave part of the electromagnetic spectrum. The instrument is called a Dicke radiometer; its principles are incorporated in modern instruments designed to do the same job. With three of his colleagues, Dicke pointed one of these instruments at the sky, looking to see if there was any background of microwave radiation from the external galaxies. One way of interpreting the strength of such radiation is in terms of temperature; Dicke and his colleagues concluded that there was a background radiation with a temperature below 20 K, the limit that could be set by their instrument, and they wrote a paper reporting this result. It was published in the *Physical Review*, in the same volume in which Gamow's 1946 paper on nucleosynthesis appeared. The paper by Dicke's team appeared first (volume 70, page 340); Gamow's came along a little later (volume 70, page 572). There is nothing to link the two papers, but they appear in the same bound volume of the journal, and every student, or more senior researcher, in the 1950s who went to look up Gamow's paper, perhaps following the story back from the alpha, beta, gamma paper, or from the work by Alpher and Herman, literally held in his (or her) hands the evidence that the cosmic fireball really had existed. Anyone—Hoyle, Gamow, or some unknown student—looking up Gamow's paper might have come across the Dicke team's paper and put two and two together; but it didn't turn out that way. Sometimes, scientific discoveries seem

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to have a will of their own, waiting until the time is ripe for them to happen.

By the early 1960s, Dicke himself had forgotten all about this measurement. But his thoughts were turning to cosmology, and in surprising, but seemingly complete, ignorance of the pioneering efforts of Gamow, Alpher and Herman he independently investigated the implications of a model universe which collapses down from a very great size into a fireball, then bounces away from the very high density state and expands. Dicke was intrigued by the idea that the Universe might be in the expansion phase of an oscillation which could continue forever, with each cycle of expansion followed by one of collapse, each collapse followed by a bounce and a new phase of expansion. And he needed the collapse to continue down to a state of very high temperature and density before the "bounce" occurred, so that all the material in the collapsing universe would be broken back down into neutrons and protons before a new phase of expansion began—there must be no "information," as it were, carried over from one cycle of the universe to the next, and to anyone living in the expanding universe it would be just as if the universe had been created in a Big Bang.

All this was still very much in the spirit of cosmology as a game, an intellectual exercise. But Dicke's experience as an observer (albeit half-forgotten experience) set him and his colleagues on the right trail at last. He gave a young researcher at Princeton, P. J. E. Peebles, the task of working out the way the temperature of such a model universe would change as it evolved; repeating, unknowingly, the calculations Alpher and Herman had carried through more than 15 years before. Peebles found that if the Universe we live in had started out in a hot Big Bang, then it should be filled with a background sea of radiation with a temperature of about 10 K. In 1964, in the light of Peebles's calculations, Dicke encouraged two other members of the Princeton research staff to carry out a search for this radiation. P. G. Roll and D. T. Wilkinson set up a detector (a version of the Dicke radiometer), and they began to construct a small antenna on the roof off the geology building at Princeton in order to detect any cosmic background radiation with a temperature of a few K. Then, on the point of making an epochal discovery, the rug was pulled from under the Princeton team. Dicke received a phone call from a young man at the Bell research laboratories, just 30 miles away from Princeton, at Holmdel, in New Jersey. The caller, Arno Penzias, and a colleague, Robert Wilson, had been getting some funny results from their radio telescope, a 20-foot horn antenna used in some of the early experiments with communications satellites. Someone had suggested Dicke might be able to explain this puzzling cosmic background radiation; perhaps they could all get together to discuss it. . . .

The antenna had been put up to work with the Echo series of satellites. These were simply large metalled balloons that inflated in orbit, and were used to bounce radio signals around the world. They had no amplifiers of their own, but acted like mirrors in the sky, so the

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signals were pretty weak by the time they got back to the ground stations, and needed to be caught by a good antenna system and amplified considerably if they were to be any use. With the advent of active communications satellites —Telstar and its successors, which amplify the signals they receive from the ground before they rebroadcast them to other ground stations—the designed role of the antenna was at an end, so Penzias and Wilson were allowed to take the communications receiver out and turn the antenna into a radio telescope. This took several months. They wanted the new receiver to be as sensitive as possible, so that it could detect very weak astronomical radio noise. So they had to eliminate, as far as they could, all the sources of noise in the electrical systems used to amplify the radio waves from space. This noise is a bit like the static you get on an AM radio; some of the hiss of background noise is from stray radio waves (including radio waves from space), but some is just due to the inefficiency of the radio receiver itself. The static, or background noise, can be measured in terms of temperature, and the engineers working with the Crawford Hill antenna on tests with the Echo satellites had noticed that there was a little more static than they could explain in their system. In effect, the antenna was too hot; in an article which appeared in the *Bell Systems Technical Journal*, in 1961, one of the engineers, E. A. Ohm, reported an excess noise, after subtracting out everything that could be explained away, equivalent to radiation with a temperature of about 3 K. This wasn't high enough to disrupt the Echo communications system, so the engineers weren't too worried about it. But it was just the sort of thing that Penzias and Wilson had to track down and eliminate, or at least identify, before they could begin their planned program of radio astronomy research.

While Penzias and Wilson were trying to track down this infuriating source of noise in their system—even going so far as to clean out pigeon droppings from the horn itself, with no effect—the Princeton team was calmly proceeding with the plans to construct an instrument to detect the cosmic background radiation. At the same time, in 1964, over in England Fred Hoyle (that man again!) and Roger Tayler were beginning to move along the same lines, with calculations of the background temperature of a Big Bang universe today. And in the Soviet Union there was a veritable flurry of activity. Ya. B. Zel'dovich had also carried out the calculation which showed that in order to explain the observed abundances of hydrogen, helium and deuterium in the Universe then it must have started in a hot Big Bang and have a temperature of a few K today; he even knew of Ohm's article in the *Bell Systems Technical Journal*, but misunderstood Ohm's terminology and thought that his measurements implied that the background temperature of the Universe was less than 1 K. Another Soviet researcher, Yu. N. Smirnov, calculated a background, or relict, radiation temperature in the range 1 to 30 K, and, jumping off from Smirnov's calculations, A. G. Doroshkevick and I. D. Novikov wrote a paper discussing the

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implications of various existing radio astronomy measurements in terms of the microwave background. They concluded that the best antenna then existing in the world for a search for this radiation was the Bell Labs antenna on Crawford Hill, and they suggested in their paper that the antenna be used for this purpose. All of this work was being carried out, and most of it published, in 1964. The idea of the cosmic microwave background had clearly decided the time was ripe for it to come out into the open. But with all the interest in at least four research centers spread across two continents, Penzias and Wilson themselves remained blissfully ignorant of the solution to their puzzle of where the excess noise in their system was coming from.

The accounts of how that ignorance was broken differ slightly, but the essentials are the same. According to one version, Penzias had been to an astronomical gathering in Montreal, and was returning, in December 1964, in an airplane where he sat next to Bernard Burke, who was based at MIT. During the flight, he mentioned the problems he and Wilson were having eliminating the background noise from their system, and as a result Burke telephoned Penzias a few days later to put him on the trail of the Princeton group. The other version of the story has it that Penzias just happened to mention the background noise in a phone call to Burke that he initiated, to discuss other matters. Either way, there is no doubt that it was during a telephone conversation in January 1965 that Burke, at MIT, told Penzias, at Crawford Hill, that yet another astronomer, Ken Turner, of the Carnegie Institution in Washington, DC, had heard a talk by P. J. E. Peebles, the Princeton theorist, in which he predicted a background noise of electromagnetic radiation filling the Universe, with a temperature equivalent of about 10 K. Burke suggested that Penzias get in touch with the Princeton group; Penzias phoned Dicke, and very soon all four members of the Princeton team made the half-hour drive to Crawford Hill to find out what was going on. At last the theory and the observations had been put together; two plus two really *did* make four.

The Princeton team was much more excited about the discovery than Penzias and Wilson were. To the Princeton researchers, the observation was in line with a prediction made by theory (what they thought was their theory), a good example of the scientific method at work. To Penzias and Wilson, although it was a relief to have some explanation of the radio noise they were measuring, it still seemed that other explanations might come along. Besides, Wilson was reluctant to accept that the steady state hypothesis was dead until more evidence came in. In particular, the measurements had only been made at one wavelength, just over 7 cm; they would have to be made at many other wavelengths, using different receivers, before the true nature of the background radiation could be reliably understood.

So the news, although it spread rapidly throughout the scientific community, appeared in print in an extremely modest way. Penzias and Wilson agreed with the Princeton team that each group

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should submit a paper to the *Astrophysical Journal*, to be published alongside each other. The Princeton paper was much the more exciting and interesting of the two, and appeared first (volume 142, page 414); Penzias and Wilson's paper followed it, under the inauspicious title "A Measurement of Excess Antenna Temperature at 4,080 Mc/s" (volume 142, page 419). News of the discovery for which they were to receive a Nobel Prize in 1978 was put in context only by the sentence "a possible explanation for the observed excess noise temperature is the one given by Dicke, Peebles, Roll, and Wilkinson in a companion letter in this issue." But perhaps the most remarkable feature of that issue of the *Astrophysical Journal* is that *neither* paper makes any reference to the work of Gamow, Alpher and Herman. The omission was soon corrected, and later publications invariably gave credit to those pioneers, but not before they had all been deeply upset at the way their work had been ignored.

Later measurements at different wavelengths established beyond doubt that the "excess noise" referred to by Penzias and Wilson is indeed a cosmic background of electromagnetic radiation, exactly the kind of "black body" radiation, with a temperature close to 2.7 K, required by the Big Bang model of the origin of our Universe. It really is the echo of creation, a leftover piece of the Big Bang that we are able to reach out and touch with our instruments. The discovery ranks with the most important scientific discoveries ever made, and it changed the face of cosmology by making the participants realize that they were not playing some intellectual game, but were dealing with equations that really could describe the origin of our Universe and everything in it. The question "where do we come from?" moved from the realms of philosophy into the realm of science with the recognition of the relict radiation for what it was. And this is why Gamow and his colleagues were ahead of their time—because they were almost alone, in the 1940s and 1950s, in *believing* the equations. Steven Weinberg, one of the physicists who turned to cosmology once the realization that cosmology was indeed a science spread with news of the background radiation, has summed the situation up appositely:

> Gamow, Alpher, and Herman deserve tremendous credit above all for being willing to take the early universe seriously, for working out what known physical laws have to say about the first three minutes. Yet even they did not take the final step, to convince radio astronomers that they ought to look for a microwave radiation background. The most important thing accomplished by the ultimate discovery of the 3 K radiation background in 1965 was to force us all to take seriously the idea there *was* an early universe.*

Gamow outlived the discovery by a couple of years. Had he lived a little longer, or had the discovery of the background radiation been made a little sooner, he might well have at least

**The First Three Minutes*, Deutsch edition, page 132.

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shared a Nobel Prize for developing the concept of the Big Bang, a concept made real by that discovery. But Nobel Prizes are never awarded posthumously, and when the Nobel Committee decided, in 1978, that the time had come to take note of the reality of the early Universe, they were faced with what must have seemed a ticklish problem—whom to give the award to. There was no shortage of candidates. On the one hand, there was a pair of young radio astronomers who had found something funny but had no idea what it was until somebody else told them, and who even then didn't really believe it at first. On the other hand, there was a team which had between them predicted the existence of a background, built an instrument to detect it and, only a little after the fateful meeting on Crawford Hill, had found it just as predicted using their own instrument. Leaving aside all the near misses from the Russians, Hoyle and Tayler and so on, there was, and still is, a third "hand" to be considered, Alpher and Herman, the surviving members of the Gamow team, who said it all first, even though they were ignored.

The award went to Penzias and Wilson. In the circumstances, it could hardly have gone anywhere else, without being spread so thin as to be ridiculous. Or could it? I wonder if the Committee entertained, even for one moment, what would have been an inspired decision. Why, after all, could the award not have gone to the person who first reported the detection of the 3 K background—E. A. Ohm? He may not have known what he had found, but then, neither did Penzias and Wilson, and he *did* find it first.

Such speculation is idle, however. What is done is done, and cannot be undone. The same seems to be true of the Universe. It did start in a Big Bang, and has evolved steadily ever since. With that one measurement, the temperature of the Universe today, available to calibrate the Big Bang, cosmologists were able to refine their calculations and come up with what is now the standard model of creation, the story of the Universe from a fraction of a second after the moment of creation up to date. ■

John Gribbin's recent books include *In Search of the Big Bang* (Bantam), where you can find out more about that standard model of creation. He is now, logically enough, completing a book about the ultimate fate of the Universe, called *The Omega Point*, to be published by Bantam.

●The universe is not hostile, nor yet is it friendly. It is simply indifferent.

John Haynes Holmes

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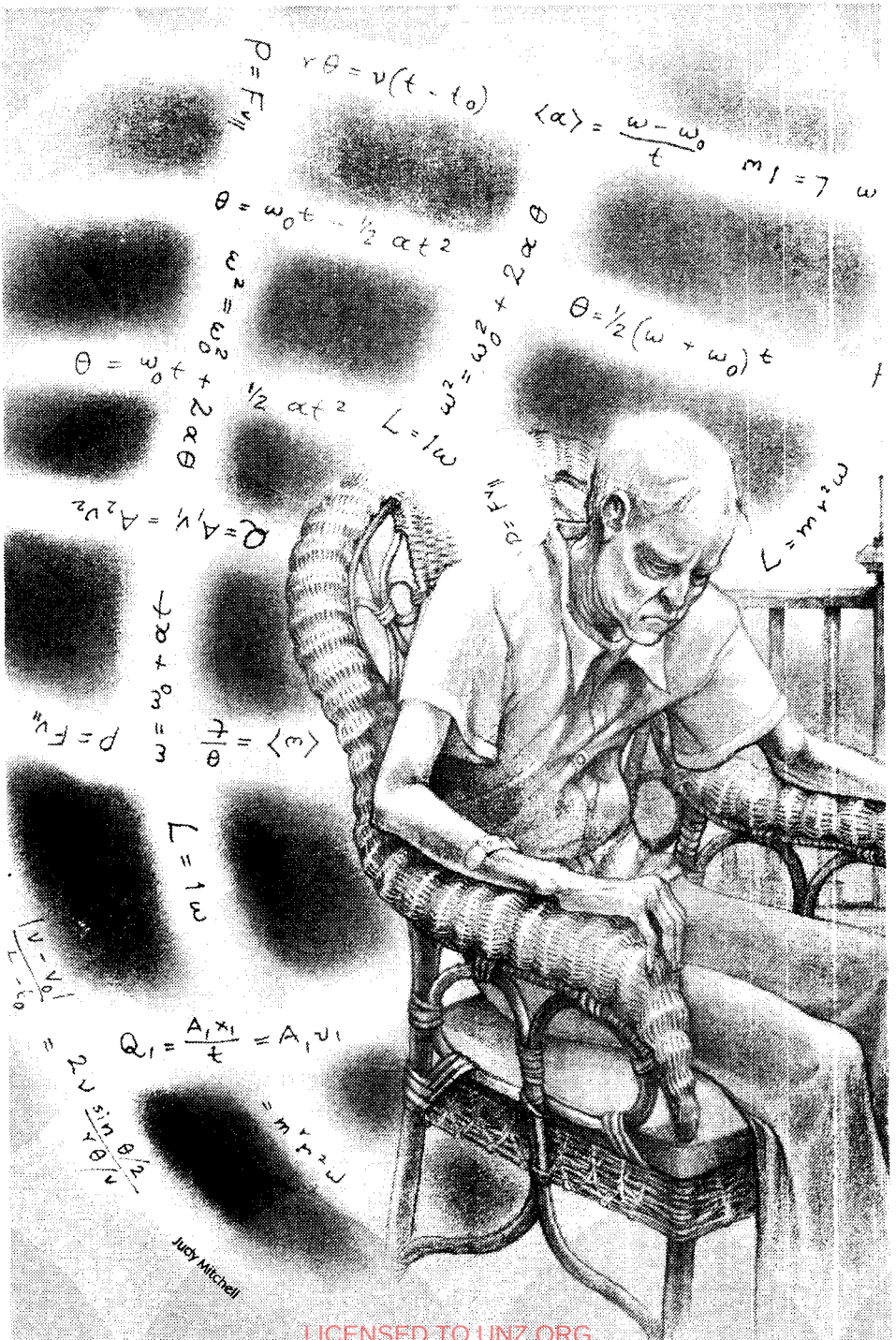
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$L = I\omega$
$Q_1 = \frac{A_1 x_1}{t} = A_1 v_1$
$= m r^2 \omega$
Judy Mitchell
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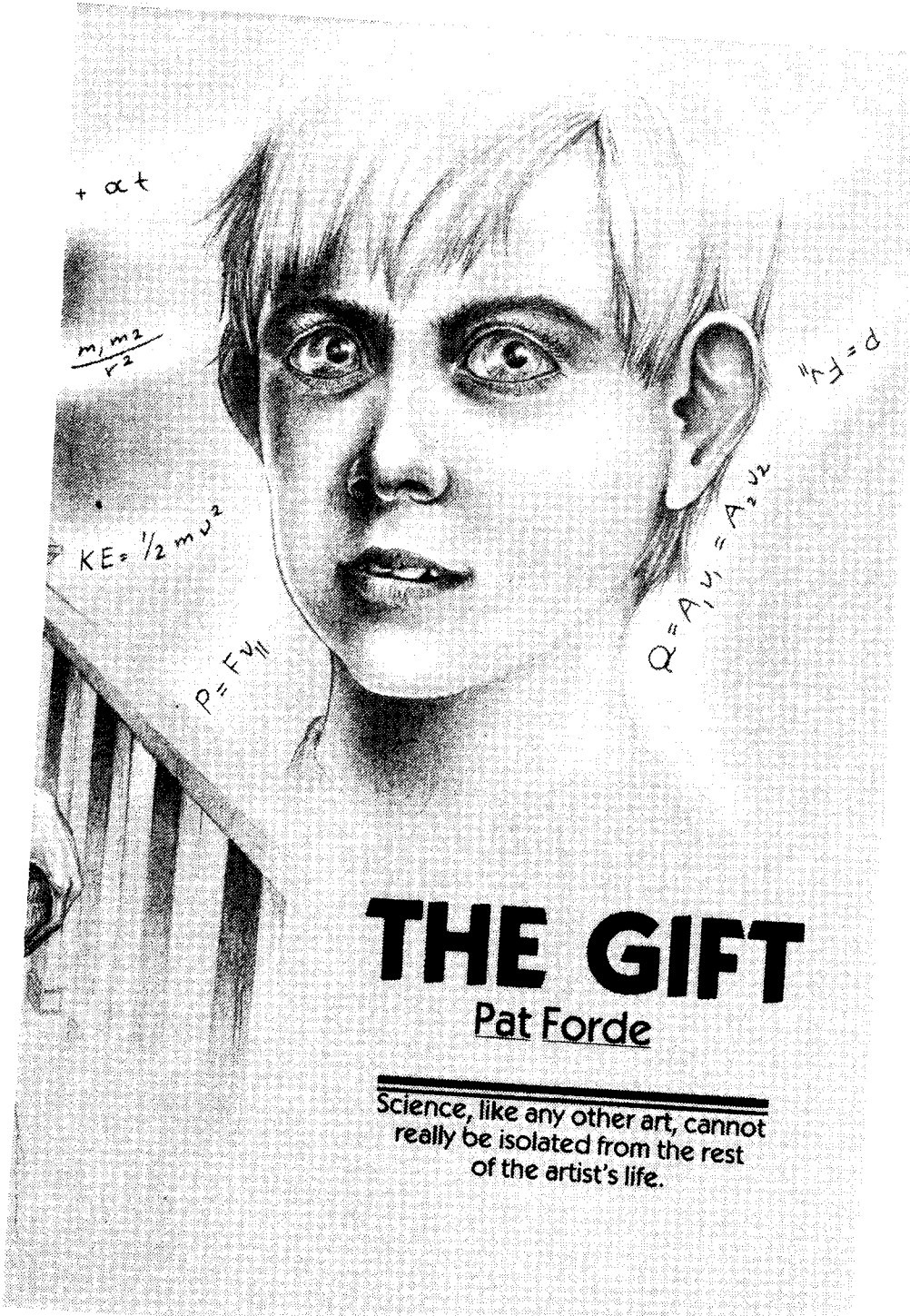

THE GIFT

Pat Forde

Science, like any other art, cannot really be isolated from the rest of the artist's life.

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Whether or not a certain item of mail arrived today was of great significance to Paul Brophy, of greater significance than, say, the sentence to a man convicted of murder. For Brophy had already received his sentence: *Leukemia*, the term to serve only a few more months, then death, no reprieve; and whether or not a letter came today would tell him, at the end, whether or not his life had really meant anything. So he waited in the shade of his porch, his emaciated hands clutching the sides of a warped wicker chair, watching the approaching postal van make its way up Park Street's curb. And at the edge of his thoughts, the lattice of equations shifted in and out of semiconscious focus.

The van slowed as it reached his house, its program pilot guiding the vehicle while the postman shuffled through envelopes. Craning his head into the bright morning sunshine, the postman turned mirrored glasses toward the porch, and called out: "Sorry—nothing for you today." Brophy opened his mouth, but all that came out was a dry clicking sound from the back of his throat; and all he could do was watch the van continue along the curb, watch it pass a fair-haired boy coming up the sidewalk, watch it stop beside a mailbox two houses down, until emptiness swelled inside him, a cold empty rush that swept away passion and hope, left him as hollow as a clay bust. *Nothing for me on July the twelfth!* he thought, numb with disbelief; he forced his eyes shut, and at the borders of his consciousness the lattice of equations rippled, unraveled, dissipated into a black void, leaving him purposeless.

Footsteps on the porch stairs. "Excuse me," said a voice.

The old man blinked; a red blur at the top of the steps resolved itself into a boy of eleven or twelve—the sandy-haired boy he'd seen on the sidewalk. Wearing multi-pocketed shorts, a red sweatshirt with the logo *GERMTOR* printed three times across it in block letters, ankle-high velcro boots and no socks, the boy adjusted a sheaf of papers tucked under one arm, then stepped forward. Beneath dark brows, his eyes appeared pigment-enhanced, the color of icicles at dawn.

Brophy managed to whisper, "What is it?"

The youth hesitated, brushing a wing of hair back from his forehead, then suddenly he stepped closer, and placed the sheaf of sheets onto the old man's lap. "I was wondering if you could help me with number eight," he said in a polite but forced tone, apparently getting something over with he didn't much enjoy. "It's about generalizing a thermodynamic *mostem*," he clarified, "and it's on the second last page." He paused, leaning forward slightly, ice eyes watching Brophy. "There's also a tricky three-parter at the very end, on merging a quark *mostem* with the old S-matrix theories."

The old man wondered, *Is he trying to be funny?* Without looking down at the papers, he shook his head. "You've got the wrong address," he said.

"This *is* 79 Park Street," the boy pointed out. "And that makes you Doctor Paul Brophy." Again he hesitated, then said, "*The* Doctor Brophy."

Something stirred at that, something Brophy hadn't felt in a long time. . . .

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Ushering the emotion away, he muttered wearily, "I cannot help you."

The boy flashed a disarming smile. "Surely a Nobel caliber theorist—"

"*The Nobel.*" Brophy's face darkened as memories arose, unbidden . . . the ivy-covered mansion just off campus, greeting him with rooms of shadows and silence each night, his loneliness turning claustrophobic . . . the stack of CERN-9604 emulsion prints sitting at the back of his office, etched onto his thoughts by an acid inspiration, the tool to destroy what might be destroyed . . . the reporters swarming around him as he left that final meeting of the Board of Trustees, trampling each other to get prime time holo footage—Brophy forced the images back down. He said, "The official announcement gave the Nobel to Pelletier; I didn't receive it, you know that." And he thought, *That's why you're here.*

For a second the boy's lips pressed together, the skin around his eyes tightening, revealing an anger or impatience that seemed wholly out of place; then the icy confidence slipped back on. He replied, "I'm not interested in your . . . experimental background." (And that, thought Brophy, that says it all; you *know*, kid.) "Just in your talent with theory." As if reciting from a book, the boy said, "You developed the lattice notation known as Princeton Standard, and you mapped out systems used in the gravity-strong force unification . . . " Here he gestured expansively, one hand swinging out over the porch rail " . . . systems that helped spread the New Paradigm all over the country."

Wonder how long it took him to memorize that. Brophy frowned, eyeing the GERMTOR logo on the boy's sweatshirt. Probably an executive's son, from a family with chartered Corporate Citizenship, out to impress the admissions board of one of the status high schools by doing a science project entitled *The Scandal of P.J. Brophy, Princeton's Fallen Theorist,* or something. Contrived praise aside, it seemed clear the boy didn't really think much of him, didn't even want to be here. "Tell me," Brophy said, his bitterness welling up, "how high is your father in Germtor?"

The youth's eyes widened, and he responded. "My dad's dead." His right hand began to finger a frayed pocket on his shorts. "My mom works maintenance in the plant on an out-of-state visa; we just moved to New Jersey last year from—"

"Why are you here?" Brophy demanded in exasperation. "To qualify for some private high school, I suppose?"

The boy said indignantly, "I'm already in high school. I told you," he said, gesturing toward the papers on Brophy's lap, "I need help to take on the Non-Newtonian."

Brophy blinked, then stared down at the sheaf of papers. Across the top sheet, four large letters were superimposed: N-N-P-C.

Princeton's Non-Newtonian Physics Competition.

His eyes flicked back to the youth. *Can he be serious? The Non-Newtonian's a senior university exam, and he hardly looks old enough for high school! He'd have to be gifted merely to qualify . . .*

The ice eyes drew him, piercing,

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magical. Releasing a breath he hadn't realized he was holding, Brophy heard himself say: "Tell me your name."

The boy answered, "Alex." He glanced over his shoulder, out to the street, as though deciding whether or not to leave.

"You live nearby, Alex?" Brophy asked quickly.

"A couple of miles from here." Alex pointed north off the porch. "In the new Core subdivision . . . you know, downtown. I'll be a sophomore at the Core High in September."

"A sophomore. How old—"

"I turned fifteen in June," the boy replied defensively. "That's why I couldn't write the last NNPC," he admitted. "Have to be at least fifteen, and be specially recommended by my school. And have a *tutor* . . . "

Brophy's vision underwent a familiar distortion, the lattice of equations rolling back into his consciousness like surfaces of imaginary microfiche text at high speed, intersecting, expanding in an ethereal Mercator's Projection that gridded out the boy and the paint-peeling porch rail and the blue sky beyond; as he watched, variable changes occurred in localized sections of the lattice, and equations sprouted into some of the holes, detailing new themes that added balance and strength to the overall mosaic. . . . The effect was partly due to the boy's presence, partly due to the prospect of revealing his theorems to a gifted mind, but mainly due to the elation Brophy felt because Alex had come to *him*, wanted to be tutored by *him*—

No. The old man shifted uncomfortably, a warm wave of guilt resonating along his spine. *That kind of vanity ruined my life once; I've resisted it for a decade, I can resist now*. He dispelled the imaginary lattice (but it would return, he knew, in the night, in his dreams, haunting him until he began working at it again), then asked the boy: "When is the NNPC held?"

"In March," Alex said, his fingers tugging impatiently at the frayed pocket again.

Eight months. The old man shook his head. "Look at me," he said at last. "Take a good long look. What do you see?" The boy eyed him uncertainly, and Brophy knew well what he saw. Skeletally thin, hair almost entirely fallen out, a pathetic bandage trying to mask the bruise on his arm, the purple spots where capillary blood vessels had leaked . . . Brophy wasn't really old, but his body was, oh yes, like the tree that survives a lightning strike: a prematurely withered husk, a shell incapable of regaining its former glory. His voice sank low: "Science did this to me, Alex; I gave and gave to science, gave everything I had, until I lost . . . all that mattered." His eyes wandered to the empty mailbox out by the curb. *Twenty-four years today*. He felt the cold inside grow, crystals freezing on the walls of his soul. When he spoke, the words themselves seemed weary. "I abandoned it, you see, abandoned science, and I don't want to be drawn back. . . . " He looked at Alex; the boy appeared unmoved, and even more impatient now. "If you want a real Nobel Laureate as a tutor," Brophy suggested, "ride the bus for half an hour, visit Princeton. You'll find Pelletier there, I've no doubt."

That got a reaction. Alex's eyes nar-

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rowed, and Brophy saw in them—what? *Fear. Yes, he's afraid. Of Ivan Pelletier?* The next instant the boy said, "My dad had cancer, you know."

"He did." *So you recognize my symptoms.*

"Yeah, he did." Again an anger or resentment tightened Alex's face, and Brophy had that incongruous feeling that the boy really didn't respect him, didn't want to be here. "But he didn't just . . . give up," Alex went on. "He liked doing pencil and ink sketches, and when he got sick, he started sketching all the time, mostly pictures of 'the baby'—me. My mom says he kept sketching, and playing with me, right up to the end." The boy hesitated, then shrugged, and finished, "He didn't feel sorry for himself, and *didn't* feel afraid of his own talent." Turning on his heel, he strode across the porch, paused at the top of the steps, and added: "I guess that's why she loved him."

With that, he marched down to the driveway.

That's why she loved him—

"Wait," Brophy called out. Alex halted on the gravel drive. "Don't leave just yet." Not sure why he didn't simply let the boy go, Brophy stammered, "I—I realize you came to me for help, and you didn't have to come at all; but Alex, there isn't any way I *can* help you. . . . " *That's why she loved him.* He frowned, considering. "Unless . . . you know, I have a book or two on Non-Newtonian theory that you won't find elsewhere, that might improve your chances with the competition." To his surprise, he found himself lifting the sheaf of papers off his lap, holding them out to the boy, and saying, "Come, help me out of this chair."

Alex reluctantly climbed back onto the porch, took his papers, hesitated, then offered Brophy a skinny arm. Gripping it, the old man pulled himself up, setting them both off balance; for a second they leaned on one another, and their eyes met, and that instant of awkwardness represented for Paul Brophy the most personal contact he'd had with another human being in more than a year. Quickly he let go, and turned to face the aluminum screen door leading into the house, afraid Alex might see how much pain standing put him in. Opening the door with one hand, he gestured for his guest to follow with the other. "Come in, come in."

A moment later they were standing inside Brophy's small front den. It was tidy, and the furnishings functional; in fact, the room was *too* functional. The shelves on either side of a fake fireplace held rows of books with identical red binding, a miniature library of the classics from some mail-order clearing house; none of them looked as if they'd been opened. On the mantlepiece sat an antique hand-faced clock, but there were no family photos flanking it, nor any personal items to be seen in the room. In one corner, a battered-looking PC filled most of a wooden desktop, the remaining desk space cramped with neat stacks of printout.

Alex said to him: "At least you still use the PML."

Brophy didn't respond. He'd discontinued his modem to the Princeton Microfiche Library long ago, but he didn't want the boy asking what the computer was used for now, because suddenly he

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felt . . . ashamed. *Top theoretical physicist ekes out final years correcting inventory errors for local retail chain.* It was just a job, one that kept him alive, kept him going, chewing away the months and years until—

Today. But the letter didn't come, my last request wasn't granted.

"So where are these books?" Alex asked, his impatience getting the better of him.

"Oh . . . " Brophy squeezed at a throbbing in his hip. "This way, this way." He headed into the hall, oblivious to the decay of the wallpaper (he'd hung it a decade before when he bought the house, and it had faded along the strip seams, revealing the passage of years as unequivocally as rings in a tree-trunk), passed through the kitchen, then stopped before a small door near the back of the house. The boy came up short behind him, his baggy Germtor sweatshirt billowing softly. Running a finger along the top of the doorframe, Brophy raised a plume of dust, and knocked off a key; he picked it up, polished it on his sleeve until it gleamed.

"Haven't opened this in a long time, have you?"

"No," the old man agreed. He remembered swearing he'd never open it again. . . . *I'm doing this for the boy,* Brophy told himself, *only for the boy.* He turned the key in the lock, then tugged at the handle a few times before the door grudgingly creaked open; inside, a narrow staircase wound down. He murmured, "Should be enough light to see by coming through the windows below," and slowly led the way into his basement.

Alex's eyes adjusted to the dimness first. Standing on the last step from the bottom, he peered around, and whispered, "Wow, there's a lot of them."

Books were stacked everywhere. On shelves, in boxes, overflowing onto tabletops . . . the library of a once-famous scientist, completely blanketed with dust. *Let them rot,* Brophy had thought when he'd dumped the books down here; but he had locked the basement door because he didn't really want to see it happen. Once this collection had been his pride and joy; and now, as his eyes finally focused, he wished he could reach out and grab the scene, shake it like one of those water-filled Christmas ornaments that snowed when jostled, making everything bright and cheery again.

The boy brushed off a nearby stack, and frowned along the titles. "All these are in some other language . . . "

"Chinese," Brophy said, as a phrase surfaced from memory: *To understand the river, I followed it to its source.* "The native language of the New Paradigm," he explained. "China's the birthplace of Non-Newtonian science, you know."

Alex cocked his head to one side, looked at him skeptically; Brophy suddenly felt certain the boy did not believe in him. *He has no faith in me, yet he comes to me for help!* It made no sense: why would anyone ask a scientific outcast, shunned by every respectable institution, to be his tutor?

"Well, *I* can't read Chinese," Alex said.

Brophy assured him: "The book I have in mind for you's in English. If I can find it . . . " He wandered into the basement, and gradually felt himself

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drawn towards a certain box on a certain shelf. . . . He smiled. *I still know where each one lies, he thought, after all this time, under all this dust.* Taking the box down, he scooped spiderwebs from the opening, drew out a manuscript in a plastic cover, and opened it to the first page.

The line under the title read: *Translated from the Cantonese by P.J. Brophy, Ph.D.*

And he remembered.

All the days spent studying linguistic diskettes, all the nights hunched over yellowing dialect manuals, striving to preserve the poetry of the original, to capture its elegance in English. It was a rare thing—an Oriental masterpiece of science, translated by a Westerner who grasped the subtle genius of the original phrasing. During his undergraduate days, Brophy taught himself Cantonese simply to understand this one book, the lifework of China's most controversial theorist; and had he won the Nobel, his translation of it might well have been *the* fundamental text of New Paradigm physics.

But this remained the only existing copy.

Most of it will be beyond the boy, until he's several years older, Brophy thought. *But it should point him in the right direction.* He glanced up from the cover, and saw Alex lift a framed photograph off a shelf, hold it up to a shaft of light.

The boy turned to him. "She's pretty," he said.

Brophy crossed the basement in two steps, took the photo, dropped it face down on a tabletop hard enough to crack the glass inside the frame. He turned, leaning back against the table's edge. "That was my wife," he breathed. "She's—dead."

Alex looked at him as if he was crazy. He shifted, began tugging at his frayed pocket again. "What's the book?"

At least his lack of patience serves to change the subject. Brophy handed him the translation. "A rare one, Alex . . . " Out of the corner of his eye he watched a shroud of dust settle over the broken photograph, burying it once more. " . . . One even the PML doesn't have." He swallowed dryly, then finished, "If you learn even a few of its secrets, I've no doubt your teachers will recommend you for the competition."

The boy appeared lost in thought, turning the book over in his hands. "You wouldn't happen to have any others as rare as this one," he began finally, looking up. "For instance, any by Pelletier. . . "

Suddenly Brophy had it. *He idolizes Princeton's great laureate, Ivan Pelletier. Yet he's afraid to seek Pelletier's help . . . must be insecure about himself, about his gift.* The old man nodded slowly. *So he came to me, the washed-up theorist, the fake: that way if he* is *recommended, the NNPC boardmembers will refuse to recognize me as a legitimate tutor, and they'll accept that he did it on his own.* That *ought to boost his confidence.*

Brophy grimaced. Perhaps he hadn't guessed the exact reasoning, but he was probably close. Disappointment like a bad taste in his mouth, he replied, "I don't have any of Pelletier's works." He was angry then, and considered taking his precious translation back from the boy, until he realized: *It doesn't*

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matter. This boy's too young anyway, far too young to appreciate what it could teach him. As it is, he'll be extremely lucky if it helps him qualify for the competition. Brophy muttered, "Now where did I leave that key?" and patted his pockets, and a phrase popped into his head: *Dust on top, but the key gleams beneath . . .*

Alex was already starting up the staircase, tucking the translation under his arm with the sheaf of NNPC papers. Brophy found the key, then followed more slowly. By the time he reached the top step his hip was throbbing again, and he was out of breath; he felt thoroughly exhausted. He rested a moment, then locked the basement door, and led the boy through the house and onto the porch.

Across Park Street children were playing beneath a large chestnut tree; a driverless bus passed close by, sunshine flaring across its wide windows as it glided out of the chestnut's shade. It was almost noon. Alex turned to him. "I promise I'll get this book back to you as soon as I'm finished."

"No need to do that." Brophy's hip was aching so badly that his left leg felt numb and the muscles of his back were cramping. He eased himself down into the wicker chair, thinking, *Have to put in my time in the hospital soon.* He said, "I'll probably have moved from here anyway; you keep it, Alex."

The boy nodded. "Well—here." He handed Brophy the NNPC sheets. "My answers are written on those. Maybe you'll get a chance to read them sometime."

"Maybe I will." The boy turned to go, and Brophy added, "Work hard now; keep in mind how good it'll feel to qualify for the NNPC at only fif—"

"You misunderstood," Alex said, frowning back at him. "I've already *been* recommended; the papers went through on my birthday, I'm officially entered for next March." He winked at Brophy, as if sharing a secret. "The truth is," he said, "my counselors think I can *win* the competition."

Flashing a brief smile, the boy stepped down from the porch, headed off across the sunlit driveway.

Brophy's eyes turned to the papers in his hands. Flipping the cover sheet, he stared at the answer scribbled across the first page.

And stared.

And this time, as the lattice of equations came flowing back, more balanced than before, this time he didn't try to resist . . . .

September.

The knock came while Brophy was working at the battered PC in his front room. He stood, flicked off the terminal, quickly crossed the room to the door. Trying to remain calm, he opened it.

"Hello, Doctor."

"Alex." Brophy smiled broadly. "I was hoping you'd return."

The boy gave him a noncommittal nod. This time he wore black cords and a handknit black sweater with the monogram *A.L.H.* sewn into the left breast; he had a metallic-gray backpack slung over one shoulder, his cheeks were flushed from the autumn air, and he was looking at Brophy in a way that seemed different from before, somehow. "I wasn't sure you'd still be here. . . ."

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He paused, noticing Brophy's arms. "Hey. No bruises."

"No." The old man shrugged, smiled again. "I've been feeling a little better lately." He reminded himself not to wonder how long the recovery would last. "Well, come in, come in! We've much to discuss."

Stepping through the doorway, the boy slipped off his pack; Brophy ushered him into the front room, and went back to the kitchen to put on the kettle. When he returned, Alex was seated at the fireplace end of the room's solitary couch, the change in his manner more evident: he regarded Brophy with suspicious expectation, as if the old man might come out with something astonishing at any moment, like a forgotten carnival magician with untold tricks left up his sleeve. Patting his backpack, the boy said, "I've brought your book."

Brophy lowered himself onto the swivel chair next to his PC. "You're finished with it?"

"Well . . . " He shook his head. "Actually, I was hoping to keep using it a while longer." Reaching into the pack, he drew out the thick translation. "Actually," he said, "I came to ask you some questions about it."

"Ah." Brophy nodded. *He recognizes the importance of the work: he just doesn't know why someone capable of understanding it, of translating it, would fudge data to ensure an experiment. Probably thinks it was purest luck I picked that particular book to translate. But he wants to make sure.* Raising a hand, he said, "Alex, before you ask me anything, I've a few things to ask myself. You see, I've been doing a little reading too."

The boy glanced up at the mantlepiece. To one side of the antique clock, there were a few texts taken up from the basement; and on the coffee table beside the couch, a recent issue of *Physical Review*.

Brophy shook his head. "I'm referring to the papers you left with me . . . " This time it was his turn to watch closely. "To the solutions you came up with."

No reaction. The boy waited for him to go on.

They are *his solutions*, Brophy thought, still hardly willing to believe it. Swiveling around to the PC desk, he removed Alex's scribbled papers from a drawer.

The first time Brophy had examined the scribblings, he read only the short answers, and decided that the boy had copied the *mostems* out of textbooks. *Mostems*, or mosaic systems of equations, were complex enough structures in themselves; and these particular mosaics required a familiarity with disciplines of physics ranging from fluid mechanics to magnetic spin waves to quantum-gravitational theory. The elegance of the short ink-splotched answers indicated a talent of unusual sense and depth; one of the shortest, the *mostem* of problem three, was damn near ideal.

Then Brophy had turned to the longer problems, and that's where the scribbling ran into trouble, becoming tangled in knots of equations, becoming reluctant to push through, to pursue the *mostems* to harmonious conclusion. It was as if the scribbler grew distracted partway into the problem, and lost sight of where he was going.

These longer failures nagged at Brophy. He examined the sheets more care-

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fully, decided that the elegence of the short answers merely became obscured in the longer ones; the consistency of style throughout made it clear the solutions had not been cobbled out of texts, but were the product of one mind, an extraordinarily gifted mind.

Could it be the mind of a fifteen year old?

Brophy wondered, and he wondered. And after a time, he found himself unlocking his basement door, returning to the vast collection of books he had ignored for so long. There he found biographies of the great theorists: Niels Henrik Abel, who at sixteen spotted gaps and flaws in established scientific proofs; Evariste Galois, who by fourteen was absorbing masterpieces of analysis addressed to professional mathematicians; and of course Gauss, imagining axioms for a geometry other than Euclidean at only twelve. Was the boy another of these? Had a young Gauss, an Einstein been delivered to Brophy in his final months? He decided to wait and see: if Alex was indeed the author of the scribbled solutions, he would appreciate the significance of Brophy's translation, and eventually return. But as the weeks passed by, the old man's curiosity won out again: getting down on his hands and knees, Brophy reconnected the modem jack of his computer, then tapped into Princeton's Microfiche Library for the first time in ten years.

He didn't find any records of the boy; what he did find was documentation on the NNPC. The Non-Newtonian competition had seen dramatic changes: it was no longer restricted to Princeton, had grown into a prestigious national contest. And the library records contained the winning solutions to last year's exam, the one Alex had attempted. Brophy called those solutions onto his PC screen now, and swiveled back to face his guest.

The boy was growing restless, fingers tugging at the fabric of the couch. Quickly the old man laid the scribbled sheets across the coffee table, tapped one with a finger. "This is your solution to number three: the water drop problem." He pointed to the PC screen. "And this is the solution to problem three judged best overall last March." Brophy sat back, folded his arms. "Alex, I want you to tell me which you think is superior: the winning solution . . . or yours."

The boy groaned. "I don't see . . . "

"Please." Brophy insisted. "This may answer your questions as well."

Picking up his scribbled sheet, Alex reluctantly began comparing the two solutions. Problem three asked for a *mostem* to describe the forces at work in an evaporating water drop, and the boy's answer to it was the best of all his answers. From the force-carrying particles interacting deep inside the molecular nuclei to the surface tension and tug of gravity shaping the overall drop, Alex's *mostem* synchronized the relevant equations into one whole, relating what was happening to the drop, how long it would take to happen, and what would happen next, on several different levels at once.

Leaving the boy to his comparison, Brophy went back to the kitchen to brew the tea. A few minutes later he returned wheeling a squeaking tray-table, laden with whitener, real sugar, and two steaming cups, parked it beside the

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couch, then began sipping at his own cup speculatively. Finally the boy looked up. "I think—" Alex hesitated, unwilling to say it, " . . . my *mostem* seems better."

Brophy smiled. "You're right. Now tell me why."

The boy heaved a sigh of impatience. "Because it shows aspects of the forces . . . the interconnections, clearer than the other one."

Brophy repeated, "Tell me why."

Alex stared at him as though he'd gone deaf; then he frowned, reconsidering. "*Why* does it show things clearer?" He raised an eyebrow, decided the old man had finally asked something interesting. Picking up the scribbled sheet again, he said, "Because . . . the way the equations fit—because the whole *mostem* is . . . " His eyes narrowed, as he tried to describe something he seemed to feel more than know " . . . the *mostem* is—well, smoother. It *flows* . . . "

"Excellent!" Brophy swung back to the PC, began keying in instructions. He talked while he typed: "Alex, a scientist's approach to science is often a reflection of his personality. I knew one researcher who always seemed nervous, rushed, a man with a short attention span. He started out studying bacteria genetics, where experimental results come quickly, in a matter of hours; he ended as a theorist only because of a lightning ability at tying up loose ends: this man tended to join research teams at the finish, crack some final enigma, then become bored and move on to—"

"Bacteria genetics . . . you're talking about *Pelletier*."

"Right." Brophy didn't take his eyes off the screen. "Ivan may have copped the Nobel, but his rushed, impulsive nature prevents him from being a great theorist. Gauss, Einstein, Archimedes, all the truly great thinkers could hang at the precipice of a problem for years if necessary, until at last they saw through to its summit. And to a certain extent, the NNPC requires similar tenacity." Brophy stopped typing. On the PC was part of the solution to problem ten, the longest of the exam.

He said, "This is the final question from last year's contest, the three-parter that's said to be 'open-ended.' You know what that means, I assume?"

"It covers an area of theory that hasn't really been mapped out."

Brophy nodded. "The three-parter tests a student's ability to handle himself in frontier territory. To master it is to master the NNPC." He paused for emphasis, then added, "But problem ten was your worst failure."

Now he had the boy's undivided attention. Alex studied him, gauging something . . . He said, "Tell me what I have to do."

Brophy gazed into the half-empty cup cradled in his hands, swirled the tea. "A person's approach reflects his character, his strengths *and* his weaknesses." He pursed his lips. "There are two reasons why you failed, I think. One you've been demonstrating ever since you arrived: you lack patience, Alex, you don't stick the longer problems through, you become distracted." He set his cup on the tray table. "And two . . . you're scared to believe in yourself." The boy lowered his eyes, stared down at the carpeting. Brophy said softly, "You're so young that you

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wonder if you really *can* do all the things your teachers claim you can. But, Alex, to master the NNPC you *must* learn both patience and confidence; and that won't be easy to do in the months remaining before March."

For a while the boy did not meet his eyes. Then, looking up, he asked the crucial question: "If I do learn them, d'you think I can win?"

Do I? Brophy closed his eyes, and the infinite lattice of equations materialized in his mind, his vast internal mosaic; stripping away the extrapolative themes concerning Alex, he saw the underlying gaps and holes that reflected voids in his own life: his lack of companionship, purpose—*Only if I teach the boy will the flow in a great part of my mostem be renewed* . . . But was that really anything to go by? Was the strength of his imaginary lattice enough to bear the weight of any real decision? Or would it simply shatter, sending him into a deeper despair?

There was only one way to answer that. Brophy had been granted one last chance, and he had to try. . . . *Do I think he can win?* He glanced down at the ink-spotted sheet, Alex's water drop solution. At last he said, "There's a third thing you must learn, Alex, if you hope to win."

"What?" the boy demanded.

Brophy pointed to the scribbled sheet. "Here you allowed it to follow its course, like a river running freely from mountain to sea. It is the flow you spoke of earlier, and theorists call it *elegance*."

The old man settled himself more comfortably in his chair, and the lesson began. "A flower is a solution to a type of problem in the natural world, isn't it? And it is an *elegant* solution. That's nature's way, Alex, and what is science but the study of nature? The Chinese were the first to understand this. Truly, it is the essence of the New Paradigm: elegance, as well as function; means, as well as end. . . . "

October.

The doctor said, "Paul, you're simply in remission. Temporary, mind you."

Brophy continued to gaze into the mirror on the examination room wall. He looked healthier than he had in years: there was color to his cheeks, a glow in his eyes . . . yes, his eyes especially seemed more alive. Though they were deep brown, they had the same piercing quality as the boy's. *Dust on top, yet the key gleams beneath* . . . The old man nodded to himself. *All differences aside, Alex and I share the same inner curiosity, the same gift*—He almost laughed. *Shouldn't flatter myself! The boy's a greater prodigy than I ever was. Each week he progresses so much* . . .

"I sense more than a physical change in you, Paul," the doctor commented, interrupting his reverie. "Something new's come into your life, something that's sparked this improvement." A confiding look slid onto his face. "You've heard from your ex-wife, haven't you?"

"No," Brophy replied suddenly. He grimaced. *That part of my mostem remains unbalanced.* Pushing himself up, he turned toward the clinic door . . . then stopped. Without looking back, he asked, "How long, do you think—"

"Don't hope for too much, Paul,"

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the doctor's voice told him. "Count each day as a blessing." Then, in a frank tone: "Be prepared for the final illness at any time. It will strike hard, and fast. . . . "

Those sobering words didn't have much effect on Brophy, for the check-up had confirmed a partial recovery; all the way home he felt lighter than air.

That evening he listened to some synthesized classical as he checked over the papers Alex had left him; and later, he spent a couple of hours on his own special papers, making a lot of progress.

That night he dreamt of her, for the first time since July, since the letter had failed to arrive. In his dream she was sleeping beside him, as she had so many years before, wearing a faint smile, reaching out sleepily to take his hand, to squeeze it just that certain way. . . .

December.

On the last night of the year they worked together in Brophy's front room, drawing warmth from a rusted electric heater in the fake fireplace, young and old, exploring the power of the New Paradigm.

Alex knelt beside the page-cluttered coffee table, his hand shifting from one to another of a half-dozen sheets, penning final alterations to a lengthy *mostem* scrawled in Princeton Standard. "That's it," Brophy encouraged, standing behind him. "See the difference that makes?"

The boy rocked back on his heels, frowning. "It's—different, all right. But I didn't think . . . " He cocked his head to one side. "It's a new technique, isn't it? I mean, weaving a machine-theory theme into biophysics equations . . . "

"Just taking the generalization a step further," Brophy murmured, leaning over the table. "And it can be taken a lot further than this, believe me." He squinted at the scribbled pages. *Never would I have thought a fifteen-year-old was capable of this.* "Alex," he said, "I'm beginning to wonder if I can match your elegance."

The boy grinned. Stretching his legs, he retorted, "Blame it on that translation you gave me, *and* your tutoring." He stood up, knees cracking, and stepped over to the fireplace to warm himself at the heater. Brophy glanced above him to the mantle piece, to a holograph taken several weeks ago: Alex's automatic camera had captured the two of them out on the porch, posing with snowballs made from the year's first heavy fall. He smiled a smile that reached deep down inside, and turned back to the pages covering the coffee table. *One solitary mostem, approaching the length and complexity of the contest's "open-ended" problem.* Brophy mused, *The boy's more than I could have hoped for. Indeed, he's a young Gauss, a young—*

"There's something I have to ask you," Alex said abruptly. He turned from the fireplace, his expression taut, serious.

Brophy sighed. "I know." In gentle rebuke, he said, "You've been working up the nerve to ask me about this for months."

The boy blushed. "You don't *have* to explain it," he said earnestly. "I mean, I'm *positive* you weren't the one who faked those emulsion tracks."

You're making this more difficult, the

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old man thought. He forced himself to say, "But I did forge them, I'm afraid."

After a moment of silence Alex shook his head, whispered, "Why?"

Brophy moved around the coffee table to the couch, sat down heavily. "There was a time when my talent was first blooming in me, as it is now in you," he began, "though for me it came when I was older. Even so, I was too naive to see that talent has a darker side . . . "

And so he told the boy how he met her, how they played together as children, dated in high school. By the time his own gift began to flower they were already engaged, and he didn't fully recognize his talent until they were married. Brophy was an undergraduate then, studying physics at a time when the whole of science was undergoing a tremendous upheaval.

Twentieth century researchers spent a hundred years knocking the cornerstone out from under the physical sciences. That cornerstone was Reduction: the breaking down of all objects and events into basic laws, properties, elements. The first cracks appeared in the Reductionist approach when Newton's grand synthesis of forces and laws, unchallenged for three centuries, fell to the axe of relativity: Einstein showed that matter and energy could not be reduced, but were the same thing. By the 1950s scientists were concluding that even forces and particles were the same thing. By the nineties, construction of a powerful new booster at the brobdingnagian CERN accelerator in Geneva was completed, and the last refuge of Reductionist thinking, the quarks, drowned in an ocean of sub-quark particles. The basic components of nature had, in one man's lifetime, run the gamut from atoms to nuclei and electrons to subnuclear protons and neutrons to subsubnuclear quarks and finally to a subquark soup. And this soup was simply another of the shifting illusory levels of reality. The universe wasn't made of basic parts, after all . . . It was an interwoven spiderweb, a mosaic system of energies and forces and particles that flowed back and forth in subtle harmony, that could not be understood in terms of parts alone.

Physics was ready for a new approach. After receiving his Ph.D., Brophy joined the faculty at Princeton, and quickly established himself as the most talented young opponent of Reduction. Vaulting into the arena of champion theorists, where the race to publish first, the fight to claim credit for an idea turns fiercely competitive, he began spending more and more time at the university, and less and less time with the one who loved him. Before long he was striving for the glory of the Nobel, and her dreams of children were cast aside; she secured a job as an elementary teacher with the Mercer County School Board to fill the lonely days and nights without him.

In his thirty-fifth year, Brophy's career peaked.

By then Princeton had become the western bastion of the New Paradigm, and he its prime theorist; his postulations were gaining favor throughout the scientific world. All that remained was nature's stamp of approval: the experimental evidence that would demonstrate the accuracy of his theories. And it was coming, slowly, bit by bit, as dozens

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of universities hunted down particle tracks left in stacks of emulsion during CERN-9604, a crucial fullpower test of the accelerator's new booster. Brophy's admirers in the Swedish Academy of Sciences jested that his name was already engraved on the Prize for physics; it was common knowledge that he had no challenger. Of course, at the top he had no time at all . . .

Eight months before the Nobel announcements, she left him. As usual, he walked into their ivy-covered house just off campus in the middle of the night; only this time there was a letter waiting for him on the kitchen table *. . . tried so many times to tell you it wasn't enough, but Paul, you wouldn't listen . . . your real love is your work, you know that . . . show me you really care, this once, and let me go . . .*

Brophy lasted seven days, seven days of coming home to emptiness and silence. The house seemed wrong without her, everything seemed wrong.

"It was as if . . . " Brophy paused, gazing across the coffee table at Alex " . . . as if my whole life was a *mostem,* and finally I could see how unbalanced the systems were. A few equations representing my talent had controlled all my actions, with vanity and the glory of the Nobel as the major themes . . . "

"So what did you do?" the boy asked.

"I—I'm not really sure. Wandered around aimlessly for a few days . . . I ended up in my office, staring at the walls, staring at the stack of emulsion prints on my shelf."

"The one you tampered with."

Brophy nodded, his expression grim. "I wanted to betray my gift, as it had betrayed me; I hated it, hated myself for letting it control me. So I reproduced two of the prints with new tracks . . . " He looked away from Alex, unable to meet his eyes " . . . Tracks of particles that would support my theories. I wasn't trying to ensure my chances for the Nobel; I was trying to lose it altogether. I *intended* to be found out." He shook his head. "When the prints were traced back to me, I was asked to leave Princeton—an incident the media turned into a spectacle. And when the Nobels were announced soon afterward, it was Pelletier who was the physics laureate, for follow-up work he did on my theories."

Alex was watching him curiously. "You still love her, don't you?" he asked.

Brophy simply smiled.

The boy shifted restlessly in his chair, and the old man decided to finish there, although the ruin of his career was not the end of the tale. Brophy had not rid himself of his gift: it continued to haunt him, the image of a life *mostem* floating through his thoughts and dreams, each time growing more vivid, until it began to take on a plausibility. Axioms and symbolic mathematical structures uncoiled in his mind, the DNA of a generalized theory, extending New Paradigm mosaics onto technological growth patterns, onto biology and economics and psychology, onto the life history of an individual. . . .

In the end Brophy began to believe in his vision; and when he learned that he was dying, he decided to listen to it. To bring flow to his inner *mostem,* Brophy had to be at peace with his love for

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her. So he wrote to her at last, asking for news of her life, her work for the schoolboard; he confessed that he did not have much longer, told her how happy it would make him if she sent a reply on July the twelfth, the date of their anniversary. All he'd needed was to feel special one last time.

Well, I have the boy now, he thought, *and he makes me feel special. With luck, he might even achieve his dream, and win the NNPC! And then perhaps my mostem will flow . . .*

February.

With two weeks remaining before the contest, Brophy decided to end the lessons, and asked Alex to come to the house once more, no books. The boy arrived just after dark, half covered in snow; leaving his coat and boots to dry in the hall, he stepped into the front room, monogrammed black sweater rolled up at the sleeves, hair damp and shining against his forehead. There was a confidence in his eyes now, a confidence that hadn't been there eight months before.

Removing a gift wrapped package from a drawer in his PC desk, Brophy held it out to the boy. "Well," he said, "I hope this helps you."

Alex accepted the package with a grin. "Can I open it now?"

"You'd better," Brophy answered in mock anger. "I've been working for months so you'd have it to read through before the exam, as a sort of final inspiration."

Tearing off the wrapping paper, the boy unveiled a thick manuscript; across the cover page was the title: *General Mosaic Systems, by P.J. Brophy.* "It's your extended theory, isn't it?"

He nodded. "Finally got it all down on paper." *And I'm giving it to you, Alex,* he thought, *and through you to the world. The mathematics and logic may seem a little strange, but the implications are revolutionary: a union of the physical, technological, social sciences, with harmony the key. . . .*

The boy read the manuscript's dedication; a single tear ran down his cheek. Unable to speak, he suddenly stepped closer, gave Brophy a hug.

The old man hugged him back, saying, "You're going to do great, Alex. I'm sure of it." He let him go then, and looked into the boy's face. "These last few weeks I've been going over ground you're already sure-footed on, holding you back from other things: those school friends you mentioned, that indoor soccer team. I guess I just didn't want to accept that you're ready."

Alex nodded. "Me neither."

"Well, you *are* ready . . . " Brophy eyed the monogrammed sweater " . . . Alex L. Houston. Is it Louis, or Lawrence?"

"I *wish.*" The boy's expression turned sour.

"Hmm. Something *awful* that begins with 'L' . . . "

They talked and teased each other for another hour, stretching out the moments until finally Alex had to leave. Afterwards, Brophy sat for a time in the front room, gazing at bookshelves filled now with dog-eared favorites from his collection in the basement, before heading off to bed.

Then he dreamt again, this time of winning the Nobel, or perhaps of Alex

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winning the NNPC, he couldn't tell which. There was a crowd of scientists around him, all inquiring about his new theory; and somewhere in the crowd, she was there, reaching out as he passed to squeeze his hand that certain way.

April.

Hands trembling, Brophy managed to hit the MAIL/NEWS key on the PC board. His terminal flickered, then the front page of the PRINCETON DAILY NEWSFAX leapt onto the screen. Most of it was taken up by a holo of Alex, and the accompanying headlines: FIFTEEN YEAR OLD PLACES THIRD IN UNIVERSITY COMPETITION —REVEALS CONTROVERSIAL NEW THEORY! Brophy had heard it all from the boy himself days before, but it thrilled him to see it in the news. Everyone was hearing about Alex now, and all because of the contest's 'open-ended' problem.

Alex hadn't even finished the NNPC: he'd jumped ahead to the final three-part problem, and become absorbed. This year it asked for the development of a full spacetime *mostem*, and what the boy proceeded to map out went beyond all previous descriptions. Incorporating an expanding universe theme into the *mostem*, he translated it into a biological growth process on the grand scale; what emerged, through the New Paradigm's interwoven approach, were places where nature's limits were undergoing rapid differentiation, localized areas far off in space and time that had different speeds of light, different fine structure and gravitational constants. Already, a few Princeton scientists had begun employing Alex's equations to explain a host of astronomical nightmares: quasars, exploding galaxies, giant black holes . . .

The old man smiled to himself. *The first triumph of my generalized theory, and the first in a long series of triumphs for young Alex Houston.* He searched further down the page . . . *teachers have noted a growing involvement with classmates and in extracurricular activities, including indoor soccer.* The boy wasn't going to let his gift control him; he was bringing the balance of the New Paradigm to his life. But that wasn't what Brophy was looking for—

There. At the end of the article: *An award ceremony is scheduled to take place at Princeton Core High School on May 31. The NNPC Third Place honors will be presented to the sophomore before a gathering of distinguished Princeton physicists, members of the Mercer County School Board, and—*

Brophy licked dry, cracked lips. So it was true: the Board *was* sending representatives. . . . *She's a counseling specialist now, and Alex's within her jurisdiction. She might be there.* He switched off the PC, hands still shaking. His arms were swollen, his whole body ached; in three days he was due to enter the hospital. But, somehow, he would make it to the boy's award ceremony, he had to. Beyond the borders of his consciousness, the inner *mostem* floated, still unresolved. . . .

Brophy squeezed his trembling hands into fists. *Let me live until the ceremony,* he thought. *And please, let her be there.*

May.

Clutching his pink release form as if

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it were a winning lottery ticket, Brophy laboriously followed a student usher through the scarred corridors of a punched-out office structure, the Core High School, an artifact of the age of home PC's and decentralization of work. He was late; and he was glad to be ushered in through the back hallways, because today he felt like a slug crawling from under a rock: Doctor Paul Brophy, the fraud, creeping into the light after all these years.

The girl led him into a cluttered room just behind the gymnasium stage, settled him into a chair, then disappeared through the curtains. It was dark, but Brophy could hear a murmur from out on stage, a familiar voice congratulating Alex on his achievement. Apparently the presentation of the award was already over.

" . . . And now, I give you Alexander Lewellyn Houston."

Lewellyn. Brophy smiled, pictured the boy wincing.

"Thank you." Alex's voice barely reached over the loud applause. "During the past month, I've attended several ceremonies, but today's is the most special of all to me. . . . "

Slowly the old man got to his feet, pulling on the curtains for support. He would listen for the right opportunity, then peek through to see if he could make out faces in the audience. From back here, the view should be good.

" . . . to be in my own school, among friends and teachers," the boy's voice continued, "and, of course, it's exciting to be on stage with such important theorists. But today is really special because I have the honor of introducing to you someone whose talent I will never equal. The new methods I used on the NNPC are methods he discovered, after ten lonely years of searching; for this man has struggled with science, alone, without reward, for more than a decade.

"You see, ladies and gentlemen, this is *his* moment. Finally, you are gathered to honor *him*. May I present the greatest scientist I know, Doctor Paul Brophy . . . "

The curtains parted, and Alex stepped backstage to take his arm. Beyond him, Brophy saw several Princeton physicists rising to their feet, including the familiar figure of Ivan Pelletier, all of them smiling at him. The old man felt his eyes water—*No! If I cry, I won't see anything*—but he couldn't help it; quickly he looked beyond the lights into the blurring audience, thought he saw a woman standing up to clap—*Is it she?* Then the entire gym was joining her in a standing ovation, and her face was lost in a sea of faces, and Brophy's tears dissolved them all into a featureless haze.

Reporters surrounded them as the applause died away, nudging the boy closer, cameras flashing to get a shot of them together. Brophy pushed to get another glimpse into the audience; the crowds were starting to disperse. He cursed his tears. *I'll never know if it was she*, he realized despairingly. *I'll never know, never know . . .*

July.

It was quiet in the hospital room, it was dark. For Brophy, the passage of time was marked by intervals of agony. Now and again, the pain seemed to blot out his senses; already, his eyesight was

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gone altogether. So when the nurse ushered a visitor in through the door, he didn't bother to look up. He just lay still, listening, hoping . . .

"Hello, Doctor Brophy."

But it was only the boy.

Alex was saying something: "Pelletier . . . your manuscript. It's going to be published."

Brophy moved his lips, tried to say, *Thank you, Alex.* But he did not hear himself speak.

For a moment there was silence; then he felt the boy's breath near his ear. "I've come to make a confession," Alex said to him. "Back last summer, that first day I met you . . . I really didn't believe in you."

Why is he telling me this now?

The boy went on: "I didn't even want to try you as a tutor. I . . . had to be persuaded. I promised not to tell, you see . . . but I guess it's okay now." Another pause, then: "It was the lady from the schoolboard, the counselor; she came to me, and asked me to give you a try . . . pleaded with me, said it was really important to her . . . that you'd asked her to send you something, but it wasn't right, it would only make you wish . . . she said she wanted to send a much better gift on that special day, one that would help you find yourself again. She said that gift was me. . . . "

Another wave of pain swallowed Brophy, but this time it didn't seem as bad.

" . . . loves you very much, Doctor Brophy. I just wanted you to know that."

And somewhere, everywhere, all around him yet deep inside him, his life *mostem* was flowing, attaining harmony, the mathematical symbols of the lattice blended into a beautiful multitude of colors, the spectrum of his innermost feelings . . . Brophy reached out to Alex, reached out; finally he realized the boy had gone.

And a few hours later, in the darkness of his last night, the door to his room opened for one more visitor. He heard shoes click across the floor, heard the chair beside his bed creak as someone sat in it. Then a hand slipped gently into his, and squeezed it just that certain way. . . .

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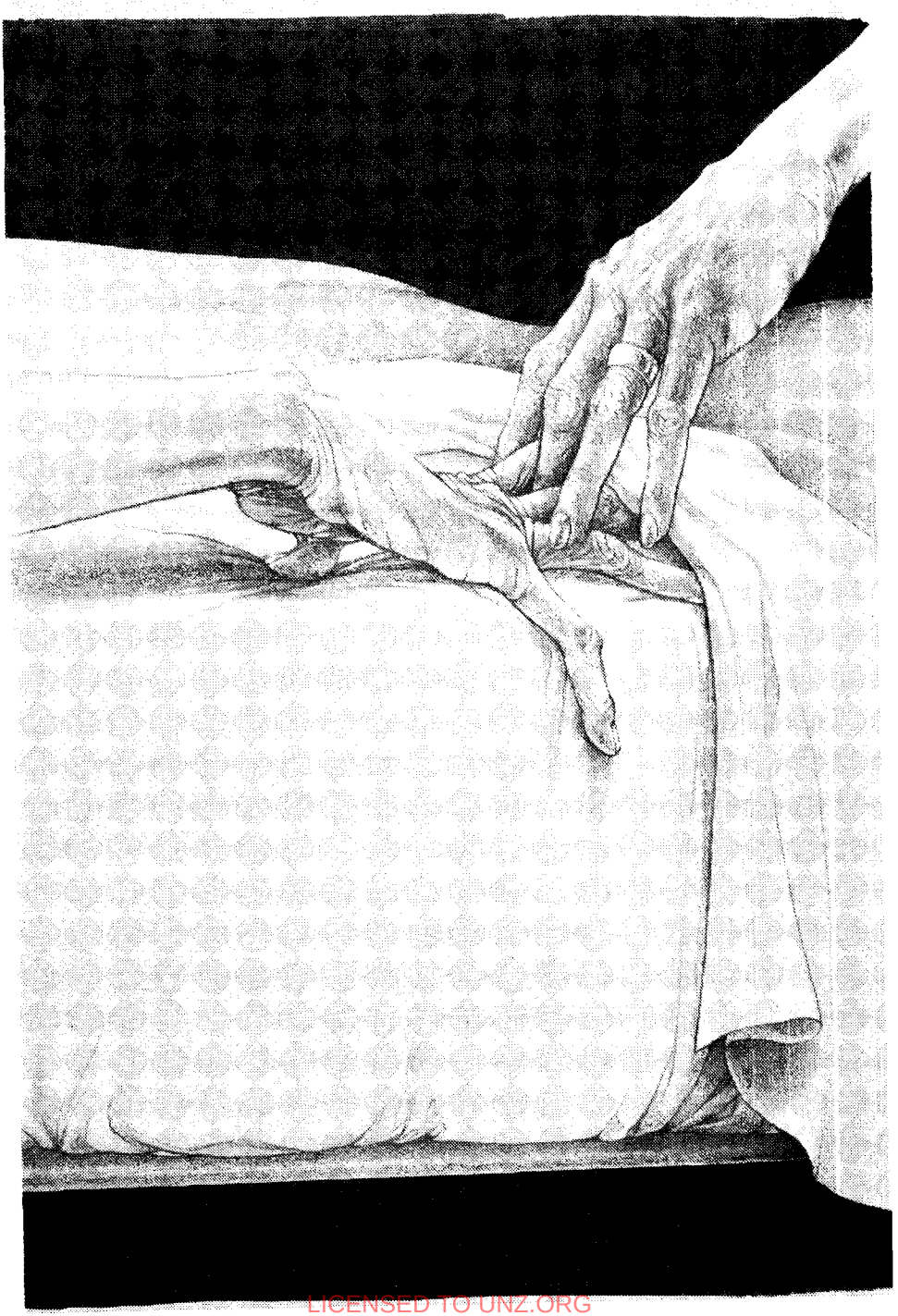

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on gaming

Matthew J. Costello

The story today is about the effect of mail on a working journalist.

Namely, me.

First, the happy part of the story.

I received a letter from some enlightened soul, with two dollars attached. He said he had bought and played my *Alone Against the Dark* solitaire for *Call of Cthulhu* (from Chaosium Inc., in case you're interested) and found it to be the best role-playing adventure, solitaire or otherwise, that he had ever played.

And the two bucks were for me to go buy myself a tall, cool one.

Made my day, it did. It's not often you hear from such an astute reader.

Then—the same week—I got another letter.

It came with a clipping from a California newspaper. It seemed that some nineteen year old was out playing with one of the lazer game guns at night with some friends, and a cop shot him.

Bang. Dead.

Of course, there was terrible remorse on the part of the cop and the paper labeled it a "tragedy."

The letter writer, though, went on for three carefully written, intelligently organized pages calling into question nearly all the games I review. With their emphasis on conflict and combat, especially such simulated shoot-em-ups like *Photon* and *Lazer Tag*, don't these games promote a too easy acceptance of violence and death? And, the writer went on, nearly all the games I cover have conflict as a major theme.

Now some of the material in the letter, like the writer's personal background, explained why the correspondent felt so strongly. Does he object, I wondered, to violence in the SF stories he reads, or the bloody scenes on the evening "news," or violence-laden films? But despite some flaws in his argument, the letter gave me pause. Lots of it, if I can use a malapropism.

I decided to look over *Analog*'s recent reviews. True, there was a nifty computer chess program and the nonviolent space navigation challenge of *The Halley Project* but there was also the robot bashing of *BattleTech* and the mindless exploits of *Infiltrator*. And for real thrills and chills, I recommended *Supremacy*—a risk-like game of world domination where restraint in use of nuclear weapons is the only thing that keeps the gamers away from calling it an early evening.

But there was also *The Robotic Workshop*—a clever mixture of computer program and robot lab. And, to be sure, *Portal*—Activision's computer mega-novel of a civilization that has mysteriously vanished.

But since even chess is essentially a game of conflict and battle, albeit raised to a sublimely strategic level, I'd have to say, yeah, by and large a lot of the games reviewed have dealt with vio-

(continued on page 184)

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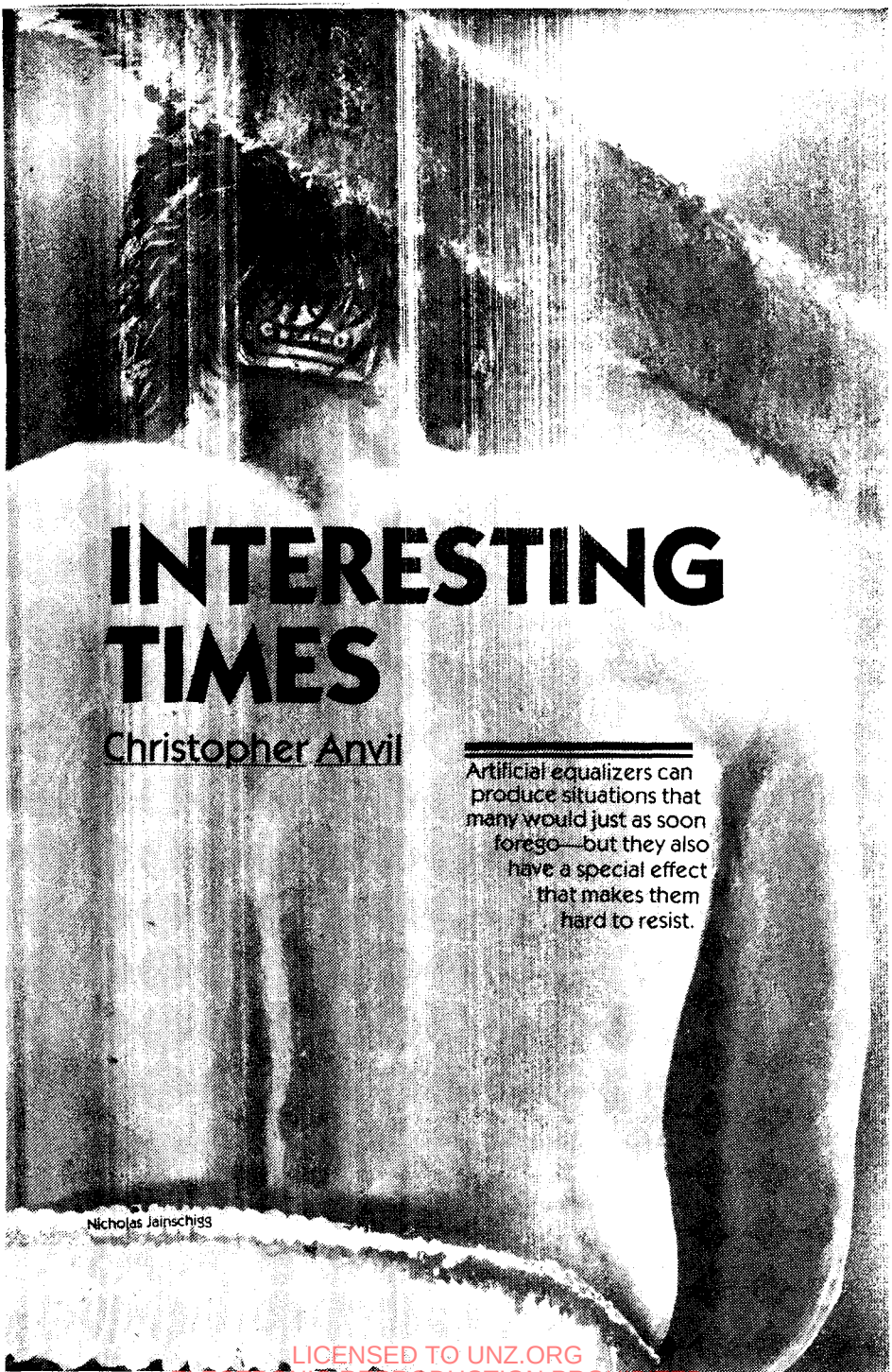

INTERESTING TIMES

Christopher Anvil

Artificial equalizers can produce situations that many would just as soon forego—but they also have a special effect that makes them hard to resist.

Nicholas Jainschigg

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Alex Bohlen, bioprogrammer for Xpert Systems Implants, sat a few yards from the boxing ring and watched Reinhardt Magnusgarten climb through the ropes. In the seat to Bohlen's right, even as the crowd around them let out its roar of approval, Ed Norton, implant surgeon, gave a grunt of disgust.

"That SOB can't stop clowning."

Bohlen noted Magnusgarten's nose-thumbing gesture across the ring toward Bisbee, the champion.

Bohlen shook his head. "The implant doesn't affect his natural ebullience."

"Ebullience? The guy thinks he's unbeatable. When they weighed in, he laughed in Bisbee's face."

Around them, the shouts of the crowd were rising to a new pitch, and Bohlen listened wonderingly:

"Okay, Maggie! Kill the bastard!"

"Magic Garden! You're in the Garden, boy! You've made it! Hey, hey! Magic Garden!"

"Come on, Maggie! Show him! We're all champs now!"

"One round, Maggie!"

Bohlen leaned toward Norton. "Are all these people crazy?"

"I don't think they are. But I think Magnus may be."

In the ring, Magnusgarten had shrugged off his robe to reveal a large pale physique, and, as the crowd gave a roar of laughter, he patted his none too muscular midsection. He then danced somewhat tipsily around in his corner, and Norton suddenly sprang to his feet, to shout to the trainer, who shook his head and leaned over the ropes to answer:

"Just the usual! You know Maggie!"

Norton sat down, and Bohlen said, "What was that?"

"I thought Magnus might be drunk. Tab says he's just horsing around, as usual."

"That's a relief, at least."

"There's a lot riding on this. Magnus could show a little seriousness."

"That would be nice. But he's done all right so far."

"Sure. Against second-rates. Strictly thanks to the implant."

"True."

In the ring, an official, arms raised, was trying to quiet the crowd. The crowd chanted back, "Fight! Fight! Kill him, Maggie! Fight! Fight! Kill him, Maggie! Fight! Fight! Kill him, Maggie!"

Someone tugged at Bohlen's left sleeve. He turned, to smile at a pretty blonde girl in the seat beside him.

"Bo," she said, "I'm scared."

"I told you you might not like it. But don't worry. It's always like this. A lot of noise and emotion. It's just the way it always is."

She shook her head. "I don't mean that. I'm afraid for Magnus. He can't possibly stand up to that man."

Bohlen followed her gaze, to see the two fighters in the center of the ring, right hands outstretched. The contrast jarred him. There in the blaze of the lights was the champion, Bisbee, a light sheen of sweat over powerful muscles, plainly trained to the peak of condition, his face blank, his gaze alert. He had a look of power and lightning reflexes.

And there was Magnusgarten, large, but more lightly built, his muscles less developed, pale, slightly pudgy, a silly

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faintly nasty grin on his face as he said something to the champion.

By some freak of acoustics, Bohlen caught the words.

Norton swore. "What did the overconfident ass do now?"

Bohlen shook his head. "He said, 'Sweet dreams,' to Bisbee."

"Great. He thinks the implant's magic. He doesn't know the difference between the second-rates he fought to get here and the champion of the world. How could I be so stupid?"

"You? What did you do?"

Norton shook his head. "I bet on him."

Bohlen grinned. "On Magnus?"

Norton nodded. "And it wasn't pennies."

The crowd was shouting and laughing. The girl said in a low voice. "Oh, Magnus." Bohlen turned to reassure her. There was a bell. A huge shout went up. Bohlen looked around.

Bisbee was in the center of the ring, his muscular arms raised to shield his head as Magnus with incredible speed landed blows to the champion's arms, shoulders, and when Bisbee tried to strike back, to his briefly uncovered head. When Bisbee turned, as if to get away, Magnus was already there, blocking him, smashing at Bisbee's well covered head and body.

The crowd screamed, "Maggie! Maggie! You've got him!"

The girl was on her feet with everyone else, clutching Bohlen's arm.

Norton was shouting with the rest of them. "Put him down, Maggie! Put him down!"

Magnusgarten hit Bisbee again and again. Bisbee kept backing and turning, keeping his head well covered. Magnusgarten hit him on the biceps, the shoulders, landed a blow to the midsection. Suddenly, Bisbee lashed out, and his punch missed, pulling him a little off-balance. Magnusgarten hit him to the eyes, and again to the eyes. Bisbee covered his face with his gloves, the sweat running down his well muscled body.

Magnusgarten laughed, stepped close, said something to Bisbee, then stepped easily around the big muscular fighter, and smashed him in the side.

As Bisbee retreated across the ring, Magnusgarten followed, hit the upraised arms, then the midsection. Bisbee covered himself with gloves, forearms, and elbows. Magnusgarten hit him. Bisbee gave with the punches.

Norton said, "Damn it! Why won't he go down?"

The big crowd fell silent. For several moments there was nothing but the sound of the blows. Then, from somewhere to the rear came an elderly, somewhat cracked male voice:

"Keep it up, Champ! He's wearing out!"

The bell rang.

Magnusgarten, breathing hard, sank onto his stool. Bisbee, the champion, sat down and leaned back. His eyes were puffed, and blood trickled from a cut in his lip.

Norton said uneasily, "This is the first fight to go a full round."

Bohlen said, "Well—Bisbee is the champ."

"I don't like the looks of it. Magnus acts tired already."

Bohlen leaned close to Norton's ear. "Remember the program."

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Norton nodded, but said moodily, "If there had been more strength in Magnus's blows, Bisbee would be down by now."

"He's no weakling. He's hurt Bisbee. You can see that."

"I know he's no weakling. But he doesn't do his part. Tab has to train him playing games and he has to do it between parties. Magnus throws the whole burden on other people."

"The reporters love it. So does the crowd."

"That won't help him if Bisbee connects."

There was the sound of the bell.

Magnusgarten came unsteadily to his feet. He sucked in a deep breath and blew it out, looking across the ring at Bisbee.

The champion, hands partly raised, stalked warily across the ring.

The cracked voice called from the back, "Watch him, Champ! He's not that bushed!"

The champion's guard jerked up higher.

At the same instant, Magnusgarten pivoted. Bisbee reeled back, hands in front of his face. Magnusgarten laughed, stepped aside, struck Bisbee's gloves as if to knock his guard down, hit him in the side, in the elbows, hit the raised gloves, smashed Bisbee in the ear, struck again to the head, where the upraised arms soaked up the force of the blows, smashed him on the biceps, again on the biceps, as if to lacerate the muscles, to destroy Bisbee's power of defense—

Bisbee backed, moved with the blows, covered himself, retreated around the ring as Magnus advanced.

The crowd screamed for action. Time and again, Magnusgarten lashed out, breathing hard, and the champion slipped away.

Among the shouts of "Yellow!" "Coward!" "Come on and fight!" came a cracked voice, "That's it, Champ! Wear him down!"

The bell finally rang.

A shout went up.

Norton sat back. "My God!"

From the rear of the arena, as the shouting died down, came the cracked voice, "He's slowing, Champ. Next round, push him a little."

Norton twisted in his seat. "Who is that? Damn it, I wish he'd shut up!"

The girl said, "Is it true?"

Bohlen looked at her anxious face. "Is what true?"

"Is Magnus tired?"

"He's bound to be a little tired."

"But doesn't the—the chip—the implant— It makes him an expert, doesn't it?"

As Bohlen hesitated, Norton leaned across him to snarl, "The bastard won't train, that's the trouble. The implant steps up his coordination. It gives him skill he wouldn't have. But he thinks it's magic and he doesn't train."

"But couldn't the implant make him train?"

Norton glanced at Bohlen. "How about it?"

Bohlen hesitated. "Maybe some day. So far, we can't do anything for motivation. I never even thought of the problem." He frowned at Norton. "Did you?"

"I thought if we got someone big and strong, who knew the rudiments, who'd take the risk of the surgery, and if we

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could get the chip implanted—I thought that would do it."

"That's what I thought."

The bell rang.

Bisbee, his guard well up, cautiously crossed the ring.

Magnusgarten, breathing hard, his hands down, stood, legs slightly trembling, in his corner.

The thin cracked voice called, "Test him a little, Champ!"

Bisbee's left hand lashed out.

Magnusgarten moved his head and body just a little, slipped the blow, and brought up both hands. The champion's right smashed solidly into Magnusgarten's midsection. Magnusgarten went back on the ropes, bounced off, and as Bisbee swung a right that missed, the cracked voice yelled, "Cover, champ!" Magnusgarten's fists flashed out to Bisbee's briefly unprotected head. The blows were solid, coordinated, and one followed another so fast Bohlen wasn't sure whether there had been three, four, or half-a-dozen.

Bisbee went down. The sound brought the crowd to its feet and silence to the arena.

Bohlen reached in his hip pocket, and brought out a handkerchief. He mopped his face and brow. "Close."

The girl said wonderingly, admiringly, "I never thought Magnus could do it!"

The worshipful tone irritated Bohlen, but he clamped his jaws shut. Norton, sweat running down his face, looking as if he had been in the ring himself, leaned across Bohlen to speak in a low voice.

"Magnus hasn't done a damned thing! Every move he's made has been programmed. I did the surgery, Bo here programmed the chip. The rest of the team sweated right along with us. And now the lazy bastard is supposed to get all the credit? When you see him, tell him to train! He could have lost this fight!"

There was an indrawn breath from the crowd. Bohlen turned back to look in the ring.

Magnusgarten, blood running from his nose and lip, leaning painfully on the ropes, stared as Bisbee stood up and the referee stepped back.

It suddenly dawned on Bohlen that the champion had stayed down for the count of nine voluntarily. Bisbee's face looked puffed around the eyes, and his lip was cut and swollen, but his movements showed no weakness.

The wondering murmur of the crowd sounded like the sea washing up on a long flat beach, and Bohlen thought of the turn of the tide.

Then the bell signaled the end of the round.

Norton leaned over to Bohlen. "Now what?"

Bohlen drew a deep breath. He kept his voice low. "The chip can judge the visual images, and give the commands to Magnus's muscles. If Bisbee knocks out Magnus's vision, or if Magnus's strength gives out, there isn't much the chip can do."

"Then it's up to Magnus?"

"What do you mean?"

"The champ's been soaking up punishment since the fight started. Magnus is worn to a thread dishing it out. This can't go on. Bisbee's going to connect. What good will the chip do then?"

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"If the chip gets no input, it has him cover. That's all it can do."

"Then when it comes to the final settlement, it's up to Magnus?"

Bohlen frowned. "I'm not sure I follow. Magnus can override the implant any time. But I don't know what good that will do. We picked Magnus because he was a promising fighter. But the skills in that chip are distilled from every first-rate boxer we could get to cooperate. The only people who could hope to equal it would be first-rate champions themselves: Sullivan. Dempsey. Louis."

"And Bisbee?"

"Maybe. Especially since Magnus is out of shape."

The bell rang, and Bohlen looked up to see Bisbee come out of his corner, and Magnus, with a look of doom, motionless, hands down, still in his corner. Bohlen glanced at the girl. Tears were running down her cheeks.

Bohlen bent over, ignoring the ring.

"Are you in love with Magnus?"

She nodded hopelessly.

From the back of the arena came the cracked voice.

"Paste him around, Champ. Wear him down."

Norton turned around.

"Who in hell is that?"

Bohlen forced himself to watch.

Bisbee had moved close. Bohlen now saw an unexpected display of skill as Magnusgarten tied up Bisbee, robbed his punches of most of their force, took the heavy blows on his arms instead of his head, blocked, turned, weaved, slipped the blows, gasped for breath, wincing with the force of the punches that did get through, spending the round soaking up punishment and dealing out in return nothing that was any real threat to the champion. Finally, the bell rang.

Norton sank down in his seat. "I thought Magnus was done. But he's still alive. What now?"

Bohlen shook his head.

Norton said, "He's more worn out than when the round started. Bisbee looks fresher."

"I'm afraid Magnus is just a sparring partner to him now. But he's on his feet. He could still win."

"Bisbee batters him on the arms. What happens when he gets Magnus so numb and arm-weary he can't cover himself?"

"I'm afraid that's it."

"Nothing programmed for this problem?"

"The program isn't cut and dried. There are stratagems, evaluations, sequences of moves. It depends on what Bisbee does. And boxing isn't all skill. It depends on condition, guts, will. We picked Magnus because he was a promising fighter. We didn't know he was going to take his training easy. I'm surprised he's lasted this long."

"I've got a lot on this bout."

"We all have. The press acts as if this decides it for skill implants."

Norton shook his head. "The technology will go on. Maybe some illusions will go."

"I can think of one—let technology do all the work. If Magnus loses, it will be that that did it."

The bell rang.

Magnus moved quickly out of his corner. After an exchange of blows in the center of the ring, the champion moved in impatiently. Magnus's brief

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show of strength gave out, but he succeeded in tying up the champion and slowing him down, though he himself landed few blows that had much force. The round passed in a silence from the crowd, and just as the next round started, a familiar cracked voice spoke up:

"Okay, Champ. Take him."

Norton gave a low curse, and crouched lower in his seat.

Bisbee crossed the ring before Magnus seemed to realize what was happening, then Magnus, nearby in the ring, pivoted to land a blow to Bisbee's head. Bisbee, seeming unaffected, smashed Magnus to the midsection, to double him over, then abruptly delivered a sequence of head and body blows that brought the crowd to its feet, and suddenly Magnus was down, near the edge of the ring closest to Bohlen and Norton.

Now, for the first time, there was a shout of "Bisbee! Bisbee!"

The girl, crying, stood up, clutching Bohlen's arm.

Bohlen realized the count had already reached three. He shook his head.

As the count reached seven, Magnus opened his eyes. He turned his head, to see the crying girl. At the count of nine, he struggled to his feet.

Bohlen, frowning, noted blood running from a cut above Bisbee's right eye. That must have happened in the exchange of blows just before Magnus went down. Bisbee, seeming unaware of it, forced the fight, and Magnus again showed his skill in defense. Just before the bell rang, Magnus landed a blow that hit the champion above the right eye. Then he dragged himself to his corner and dropped onto the stool.

Bohlen sank back in his seat.

Norton said grudgingly, "The skill is the chip's. But he's got guts, all right. I think I'd have stayed on the deck."

Bohlen nodded. "I don't know any way to program courage. Bisbee's eye doesn't look good, either."

"No. But this dents our slogan that 'Anyone's an expert with an XPert Implant.' There's more than skill involved. You can't turn everything over to the implant."

"No, I don't think anyone would care to try it. It isn't the chip that feels the blows."

The girl was sitting, trembling, with her eyes shut and head bowed. Bohlen looked at her thoughtfully, then heard the bell.

This time, both fighters were cautious, as Magnus circled to get a blow at Bisbee's eye, and Bisbee sought to prevent it. Bohlen, watching the seemingly academic series of combinations as both fighters boxed, was surprised to note how often Magnus, though plainly the weaker, still managed to score. By the end of the round, the cut over Bisbee's eye was visibly worse, and the eye nearly shut. But Magnus seemed scarcely able to stay on his feet.

Norton said, "Damn it, even if he half-blinds him, how will he put him down?"

"Be glad he's still conscious."

"If he lives through it, I hope next time he trains. Damn it, if he hadn't had an implant, he'd have trained!"

"Every time we get a technological advance, we lose something. People expect the technology to do it all."

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"Ah, it's the usual thing. Tough barbarians from the northland erupt into the tropics, and conquer the weaklings lying around in the sun. A couple of generations later, they get whipped themselves by a fresh batch of barbarians. Now we make an oil burner and put the tropics into the home. The chip is the worst. It's supposed to do the thinking and planning. The problem has been around since the Vandals, and we're losing ground."

"I wonder if actually it might be possible to somehow program the training routine into the chip?"

The bell rang.

From the back of the hall, a cracked voice called, "Champ—You've got to force him."

Norton shook his head. "That guy ought to be in Bisbee's corner. If he'd just shut up, we might live through this yet."

Bisbee, seeming to pay no attention, tried to box Magnus at long range, while Magnus tried to circle, to take advantage of the poor vision of that swollen right eye. The fight turned into a sparring match, and Bohlen, groggy himself, watched with less and less attention. Toward the end of the round, he became aware that Magnus had just landed a blow to the head. Bisbee's broad back was to Bohlen, who didn't realize anything more had happened until he saw Magnus's head snap back, and Magnus went back on the ropes. Bohlen came awake to see Magnus, doubled over, take a murderous right uppercut that straightened him up, then he dropped unconscious to the floor.

Bisbee turned and walked across the ring.

The count, monotonously intoned, reached eight, and Magnus had yet to move or open an eye.

The bell rang.

Bisbee gave his head a slight shake, and walked to his corner.

Bohlen, groggy, glanced at the girl, who sat staring dazedly at her hands, as if afraid to look in the ring. Bohlen, who felt the same way, made the effort to look up.

In the ring, officials were conferring. Someone, apparently a doctor, was examining Magnus.

The bell rang.

Norton said, "What round is this?"

"Don't ask me."

"Wasn't that an unusually short break between rounds?"

"If you can still judge time, you're better off than I am."

Magnus, his guard up, was facing the champion, who bored in as Magnus gave an exhibition of skill that reduced Bisbee to a look almost of clumsiness. By the end of the round, Bisbee's right eye was nearly shut.

At the close of the round, as Bisbee and Magnus sank onto their stools, someone cheered, and the crowd joined in.

Norton leaned over beside Bohlen. "Not to take any credit away from Magnus, but I'm wondering. Speaking as a surgeon, a mere mechanic for bodies, it seems to me an opponent could beat Magnus to a pulp, and that chip would keep calculating moves for him. The chip isn't going to get dazed at all, is it? No matter how dazed Magnus gets?"

"I've taken it for granted that if he's groggy, he can't function. It looks as if I was wrong."

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"The impression I have is that his skill improves after Bisbee knocks him half-unconscious. We never saw this before. No one ever got this far before."

"It's certainly a point. He acts dead on his feet, but his skill, if anything, improves."

"Well—let's hope he stays a little dazed. If Bisbee gets him again, I'm not sure the bell can save him."

"As it is, I think he's winning on points."

The bell rang. Again the two boxers approached each other. This time, Bisbee seemed determined to take advantage of his strength. Despite another display of skill from Magnus, the blows Bisbee dealt seemed on the edge of putting Magnus down. But when the bell rang, Magnus was still on his feet, and Bisbee's eye was almost shut.

Again the officials conferred, and now a doctor examined Bisbee.

The crowd, apparently worn out themselves, watched in silence.

The bell rang.

As the fight resumed, again Magnus was able to hit almost at will, as Bisbee covered himself, retreated, backed away, and suddenly, as if out of nowhere, smashed Magnus with his left hand, sprang forward, and moving too fast to be clearly seen, landed a sequence of murderous blows.

Again, Magnus was on the floor.

Bisbee stood over him, breathing hard, as the referee tried in vain to get him to move away. Finally, with a heavy sigh, Bisbee turned and walked away.

The count started, and reached eight.

Magnus tried to get to his feet, and failed.

The referee counted, "Nine."

The bell rang.

Bohlen sat unmoving, dazed. Around him, there was a near-total silence. Again the officials conferred. A doctor examined Magnus.

Norton nudged Bohlen. "Let me by. I think she's fainted."

Bohlen looked dully at the girl, slumped in her seat.

Somewhere, a bell rang.

Bohlen sat in a daze, then looked up without curiosity at the ring.

The two fighters were circling each other, both wary, exchanging blows meaningless to Bohlen. It dawned on him that he had missed something. Now the fight seemed almost even. It had obviously been Bisbee's at the end of the last round.

Bohlen looked away, and wondered idly if there was some food around somewhere. Then he asked himself why he felt as he did. Next he wondered how he did feel. It took a while to find a comparison. He felt as if he were a reporter in the Second World War, and the slaughter was still going on now after decades of fighting, and he still didn't know who was going to win.

The bell rang.

"Good God," said Norton.

Bohlen felt a twinge of curiosity, and glanced at the seat to his left.

The girl was gone. "What did—"

Norton said, "I sent her out. It was killing her."

Bohlen nodded absently, "Not a very doctorly way to put it. Your professional manner is underdeveloped."

"I don't feel very doctorly. I feel like a wet rag. How would you put it?"

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The bell rang, to signal the beginning of another round.

Bohlen's thoughts moved like glaciers. After a while, he said, "I'd look profound, and say she was being emotionally traumatized by this experience."

Norton, watching the ring, nodded judiciously. "There's still time for you to go to medical school."

There was a crash from just above them, in the ring, and a murmur of voices, then someone said, "One."

Bohlen looked up.

Bisbee lay outstretched on the canvas.

Bohlen stared, trying to see Magnus lying there, because it was Magnus he expected to see. But the fighter stretched out there was Bisbee.

At the count of seven, the champion tried to get up. As he turned his head, Bohlen could see that now his left eye was swollen almost shut. Bisbee fell back onto the canvas.

At the count of nine, he scrambled to his feet.

Magnus crossed the ring, hit Bisbee, and hit him again. The blows weren't heavy, but Bisbee couldn't defend.

Bisbee then covered his head. He was fighting now as he had fought in the first round, but now both eyes were swollen, and blood was trickling down as Magnus methodically opened up a cut over his left eye.

Bisbee lashed out at his tormentor, who moved easily aside, and struck back to catch Bisbee in the mouth. Again Bisbee covered himself.

Magnus hit Bisbee, hit him again. Magnus, though obviously tired, was moving with smooth coordination. Suddenly he laughed.

"Sweet dreams," he said, and landed a sudden heavy blow to the side of Bisbee's head.

Bisbee staggered.

The bell rang.

Norton said, "They've got to stop this."

A few moments later, they declared Magnus the winner, and he stood with upraised fists, smiling, as the cheers echoed around him. But Bohlen could see no one close to the ring who was cheering. He glanced at Norton, who shook his head.

Bohlen said, "What happened?"

"What do you mean?"

"Bisbee had him. Then I looked away. I was tired of watching it."

"You should have bet on it. You wouldn't have looked away."

"The last I saw, Magnus was on the mat. What happened?"

"It was the same thing again. Magnus was out on his feet, but he moved like a dream. Bisbee couldn't connect. His eyes were swollen shut, and he couldn't follow what Magnus was doing."

"I suppose I should be glad," said Bohlen.

Norton grunted. "At the end, I was hoping Bisbee would win. It would have cost me money, but it would have been worth it. Look at Magnus."

Bohlen didn't look at the ring. "He won on luck. And guts, give him that. But the bell saved him at least twice."

"That's not what he thinks."

Bohlen looked at Magnus. "He thinks he's unbeatable. Damn it! It's the implant!"

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Norton said, "And you programmed it."

"Not alone," said Bohlen defensively. "It wasn't my idea."

"I'm not blaming you. Look at me. I put it in him. What I'm saying is, he's standing up there, taking the cheers. It was luck and the implant that saved him, and you programmed the implant, and I put it in. I tell you, one slip, and he wouldn't be here. He wouldn't have lived through the operation. But is he giving anyone else credit?"

"No."

"There's a problem here, Bo."

Bohlen said, "I won't argue with that."

"It never hit me we were making a Frankenstein's monster."

"Well—I wouldn't go that far."

"I would. This isn't the only expert chip there's going to be. This is just the first. This guy is a Boxer. Pretty soon we're going to be making Soldiers. Somewhere, right now, they're doubtless asking how to make Assassins. Sooner or later there'll be a Ninja implant chip. What's it going to be like to live in the same world with this stuff? For the first time, anyone with the money, or who has a backer with the money, will be able to acquire real skill without making the effort to earn it."

Bohlen stared at Magnus, saw Magnus smile easily, condescendingly, to the reporters as they crowded around, asking him to make a muscle, snapping pictures of him with fists raised. Magnus's lip was swollen, and one of his eyes was partly shut, but that didn't dent the easy air of superiority.

Norton said, "How does he look so casual when Bisbee had him on the mat twice?"

"Three times."

Norton blinked. "That's right."

Bohlen shook his head. "Maybe it's just his personality. This may not happen with everyone who gets an implant. He's the first. There will be others. It could even become commonplace."

"Not for a while. There aren't enough surgeons who want to do the operation."

"Yeah, but—"

Norton looked at him.

"But what?"

"That's the next expert implant—the surgical chip."

"You're serious?"

"I wouldn't make this up. It's perfectly logical. The bottleneck, all along, was the interface. A big part of that is the process of implantation. We need capable surgeons. Therefore, develop an implant to increase the number of capable surgeons. That will end the bottleneck. Q. E. D."

Norton swore.

Bohlen said, "Will you refuse the implant?"

"I don't aim to end up like Magnus."

"Then you'll be passed by colleagues less capable now than you are."

"I can think of the very cretins who'd jump at the chance." He looked at Bohlen, and suddenly his eyes glinted. "And when does the programmer's chip implant come up?"

Bohlen shook his head. "Third on the list. Another bottleneck."

Norton smiled. "Programming should be a natural for this technique."

"I'm not certain it can be done. But I wouldn't bet against it."

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"There are a lot of angles to this thing. Magnus has the idea he is different and superior. I wonder how competition would hit him. I think Bisbee deserves the chance to even things up."

"Would he do it?"

"We could find out."

Bohlen laughed. "It may end up like college. Almost everybody has to have a degree, now. I can see it a few years from now: 'What field is your implant in?' "

"Not so fast. Even with lots of willing surgeons, there's still the operation. Who wants it?"

"It could end up like tonsils and adenoids. Then, after a little more improvement in technique, like going to the dentist."

"People will send their children to the chip-implanter?"

"Why not?"

Norton gazed off into the distance, and shook his head.

"There's one thing we can be reasonably sure of."

Bohlen nodded. "In one sense or another, this technology will be very educational." ■

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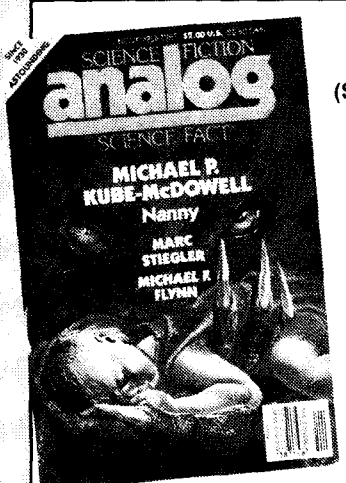

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The Alternate View

SN1987A—SUPERNOVA ASTROPHYSICS GROWS UP

John G. Cramer

Every fifty years or so a star in our galaxy explodes in a supernova, but only rarely are they visible in our sky. A supernova close enough to the Earth to be seen with the unaided eye was discovered by Johannes Kepler in 1604. In the 383 years since Kepler, astronomers have observed many supernovas in other galaxies, but there has not been one in our own galactic neighborhood close enough to watch in progress. This long supernova drought was broken early on the morning of February 24, 1987, when Canadian astronomer Ian Shelton developed a photographic plate that he had just taken with a wide-angle ten-inch telescope at the Las Campanas Observatory in Chile. Shelton examined the plate and noticed a new star. An obscure blue B3 supergiant star with the unlikely name of Sanduleak -69°202 had exploded, becoming type II supernova SN1987A. The discovery was broadcast to a data-hungry world, and the astronomy/astrophysics community has been in an uproar ever since. Before exploding, Sanduleak -69°202 had a mass 15-20 times greater than that of our sun and was located in the Large Magellanic Cloud, a sort of suburb of our galaxy some 160,000 light years distant. To the despair of residents of North America, SN1987A is visible only in the Southern Hemisphere. A friend just back from Argentina tells me that it's still quite visible there and is about as bright as the stars of the Southern Cross constellation.

What's a type II supernova? It's the explosion of a large star that has burned up all of its nuclear fuel and literally run out of gas. One might think that would produce a dead cinder rather than a giant explosion. But for stars, out of fuel does *not* mean out of energy. A burned-out star still has a very large amount of gravitational energy. As soon as the nuclear power plant switches off, the gravitational energy is "cashed in" as the outer part of the star falls inward.

The star's mantle is no longer held in place by the heat and pressure of nuclear fusion. As it falls in, the density of matter in the interior grows progressively larger. Finally the density rises to about 10^{13} grams/cm^3, about three times the density of an atomic nucleus. At this density, unless the star is so massive that the collapse continues on to form a black hole, the inwards falling material literally bounces. The density has become so large that the "Pauli repulsion," the intrinsic repulsion of one neutron for another, one proton for another, or one quark for another takes over and halts the collapse of the star.

Then two things happen. Suddenly all the protons in the star's interior are able to gain energy by eating a nearby electron and spitting out a neutrino. In the process the protons become neutrons, and the inner part of the star becomes a neutron star. While this is going

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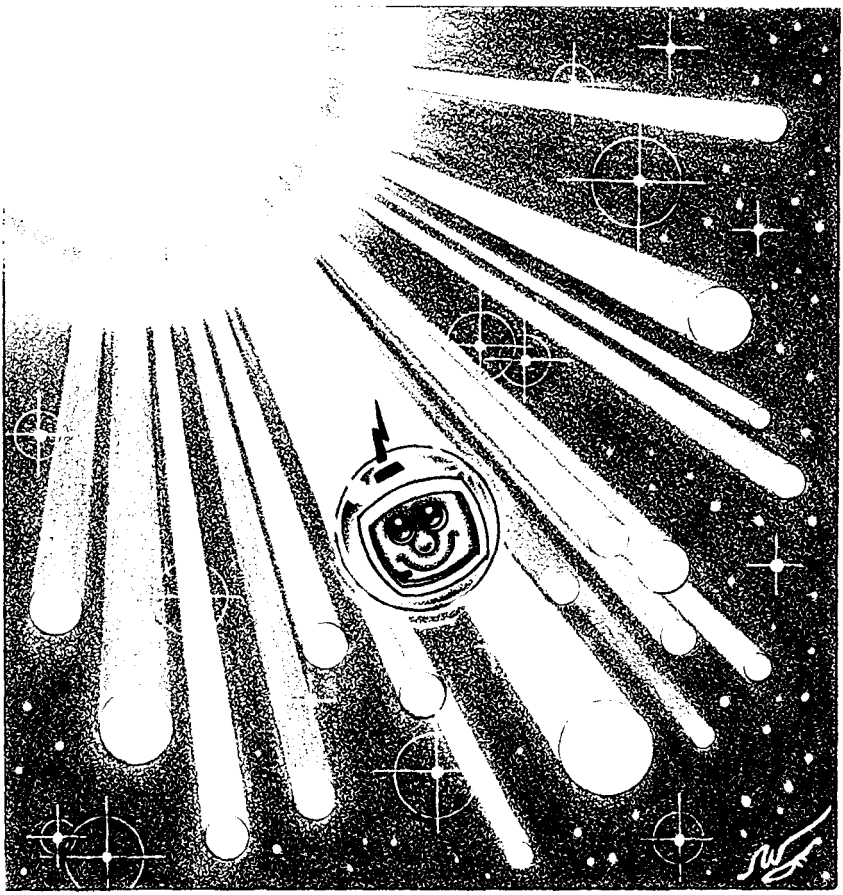

Illustration by William R. Warren, Jr. 1987

on, the outer part of the star is being blown outward by the recoil energy of the bounce. That outflow of energy is now boosted by the additional energy carried to the shock wave by the flood of neutrinos from the core collapse.

Neutrinos are normally very passive particles, electrically neutral and with a mass at or near zero. A neutrino can pass through a light-year of lead without scattering from even one lead atom. Neutrinos usually mind their own business and go their own way without much association with normal matter. But within the passage of a few seconds in the supernova, every proton in the interior of the star gives birth to a neutrino. SN1987A probably produced 10^{58} of them. All of these neutrinos streaming out from the heart of the star must travel through an amount of matter equivalent to a *few thousand* light-years of lead. Therefore, despite their inertness, these neutrinos which are carrying away most of the gravitational energy lose about 1% of this energy on their

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way out. If you were in a Jupiter-type orbit a billion kilometers from SN1987A when it exploded and were protected from the other effects of the supernova, you would be killed by the radiation damage from neutrinos streaming through your body. There are that many. About one hundred times more energy from the supernova goes into the neutrinos than into the blast shock wave, and one hundred times more energy goes into the shock wave than into visible light. The visible light from the supernova, which can outshine whole galaxies, is a minor side effect of the explosion.

When the outer part of the star lifts off in a giant release of neutrinos, superheated matter and light, it leaves behind a cooling and rapidly spinning neutron star. Why does a neutron star spin? Any star will have some rotation, and in the collapse process it is greatly magnified. Consider an ice skater doing a spin. She begins the turn slowly with arms extended, then draws in her arms to increase the spin rate. The star does the same thing, the matter in collapse playing the role of the skater's indrawn arms. A newly formed neutron star is spun up to such a high rate that it may make a complete rotation in a few thousandths of a second.

Almost a full day before SN1987A was discovered by astronomers, the neutrinos from the explosion reached the earth. Even though the supernova was 160,000 light-years away, the number of neutrinos from SN1987A was briefly about equal to the number reaching earth from our own sun. On the average the supernova neutrinos had about one hundred times the energy of those from our sun, making them more likely to react with matter. In deep underground locations in the Kamiokande mine in Japan and in the Morton-Thiokol salt mine beneath the shores of Lake Erie are large tanks containing thousands of tons of crystal-clear water monitored by thousands of photomultiplier light sensors that wait, up to now without success, for the light flash that will signal the decay of a proton (see my AV columns, *Analog* 7/84 and 3/86). On February 23, 1987 these detectors saw no proton decays, but they did see something else. In a space of a few seconds the Kamiokande II detector in Japan recorded eleven neutrino events, and the IMB detector in Ohio recorded eight. The start of the events in the two detectors was essentially simultaneous, within the accuracy of their recording clocks. The Kamiokande and IMB events are the first direct observations of the core collapse of a star. Some of the Kamiokande events were backtracked and found to have come from an approximately 20° cone that included the Large Magellanic Cloud, site of SN1987A. The data tapes containing the neutrino events were not processed until well after Shelton made the visible-light observation of SN1987A, but the neutrinos arrived about 18 hours before there was any visible indication of the explosion. The neutrinos give a prompt signal of the supernova because they are released directly by the formation of the neutron star, while the transport of light and energy through the dense mantle of the star takes many hours longer. In future supernovas the precursor neutrino flash may tell astronomers when and where to look.

In addition to the treasure trove of

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astrophysical data provided by SN1987A, it can also be viewed as an "experiment" arranged for us by nature for revealing something about neutrinos themselves. One of the outstanding problems in contemporary physics has been the question of whether, like photons, neutrinos truly have zero rest mass or whether their mass is small but nonzero, as has been suggested by a few questionable experiments and by the dark matter problem (see my AV columns, *Analog* 2/85 and 5/86). The detection of supernova neutrinos provides a means of weighing the neutrino. If neutrinos have no rest mass then all neutrinos travel at the speed of light, and if emitted together should arrive together, even after traveling 160,000 light-years. But if neutrinos have nonzero rest mass, those with large kinetic energy will arrive at a detector slightly before those with smaller energy. Since the total spread in the arrival time of the neutrinos was 12 seconds, one can use this to set a limit on the neutrino mass. To do this properly one needs to carefully model the release of neutrinos in a supernova. Adam Burrows of the University of Arizona has done this calculation and gets an upper limit on the neutrino mass of six electron volts, with a 99% confidence limit. Other calculations have given larger estimates, but most of these have not included careful modeling of the supernova and the neutrino release process. Burrow's value, if accepted, is quite important because it is smaller than the best upper limits from direct experimental measurements, and it is also smaller by a factor of about three than the mass that a neutrino would have to help with the dark matter problem.

There remain a number of mysteries about SN1987A, which are going to provide grist for the astrophysics mill for years to come. First, Sanduleak -69°202 is the wrong kind of star for a supernova. It is a *blue* supergiant, not an older and larger *red* supergiant. It is a young hot star that is not supposed to have consumed enough of its fuel to be a supernova candidate. Second, SN1987A seems to be 50 to 100 times dimmer than supernovas previously observed in other galaxies. Is this because Sanduleak -69°202 is a strange and unusual case of a supernova? Or is it just that we have missed similar ones in other galaxies because they were too dim to come to our attention?

But perhaps most mysterious of all is the fact that SN1987A keeps getting *brighter*. The usual pattern for supernovas in distant galaxies is that the light output begins to dim after a few days, dropping very rapidly for a while and then easing into a more gentle exponential falloff. SN1987A started by following this pattern. But after a few days of dimming, the light intensity began to rise. And it has been rising ever since! From early March to this writing in early May it has shown no signs of decreasing or even of leveling off. SN1987A breaks all the rules.

So what's going on? How can all of these strange characteristics be explained? It's much too early for these problems to be well and truly solved, but let me tell you about a picture that seems to be emerging from the bewildering array of facts. Let's assume that the reason SN1987A seems unusual is because we've never been able to ob-

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serve such a dim supernova before. It takes a much brighter one to stand out enough to be observed in a distant galaxy. But SN1987A is smaller and dimmer. Since it *is* smaller, the spinning neutron star in its center plays a larger role as an energy source. Such stars have truly enormous magnetic fields and make a full revolution in a few thousandths of a second. In the process they radiate enormous amounts of electromagnetic energy. This radiated energy, assuming a middling fast rotation rate for the newly born neutron star, is about equal to the amount of visible light now emerging from SN1987A. The neutron star would be superheating the plasma shroud of the supernova from within, the plasma radiating the heat away as visible light. This may be the "power plant" that keeps increasing the light output of SN1987A. If this is so, SN1987A should be a prominent feature of the Southern Hemisphere for some time to come, at least until the neutron star loses some of its juvenile spin and the plasma cloud spreads enough to cool down.

In any case nature has given us a rare gift, a ringside seat at the metamorphosis of a star from blue giant to neutron star. Astrophysics has begun a new era, and the new science of extra-solar neutrino astronomy has just been born. ■

Further Reading

Supernova 1987A:

"Supernova 1987A: Notes from All Over," M. M. Waldrop, *Science* 236, 522 (1987).

"Supernova Shines On," R. A. Shorn, *Sky & Telescope*, 470,(May 1987).

EDITORIAL

(continued from page10)

sults before they go to bed? Isn't the *validity* of the results more important than the exact hour when anybody hears them?

I realize also that my counterproposal would involve a small restriction on freedom of speech and press—but at worst this is nothing more than a three-hour delay on *when* something can be said, not a ban on its being said at all. I'm at least as wary of such restrictions as anybody I know, but this seems to me a special case which can be justified a good deal more easily than some of the exceptions already being made.

After all, if we're going to live on planets, whether by choice or necessity, we might as well face the fact that planets *act* like planets.

They even spin, legislation notwithstanding. ■

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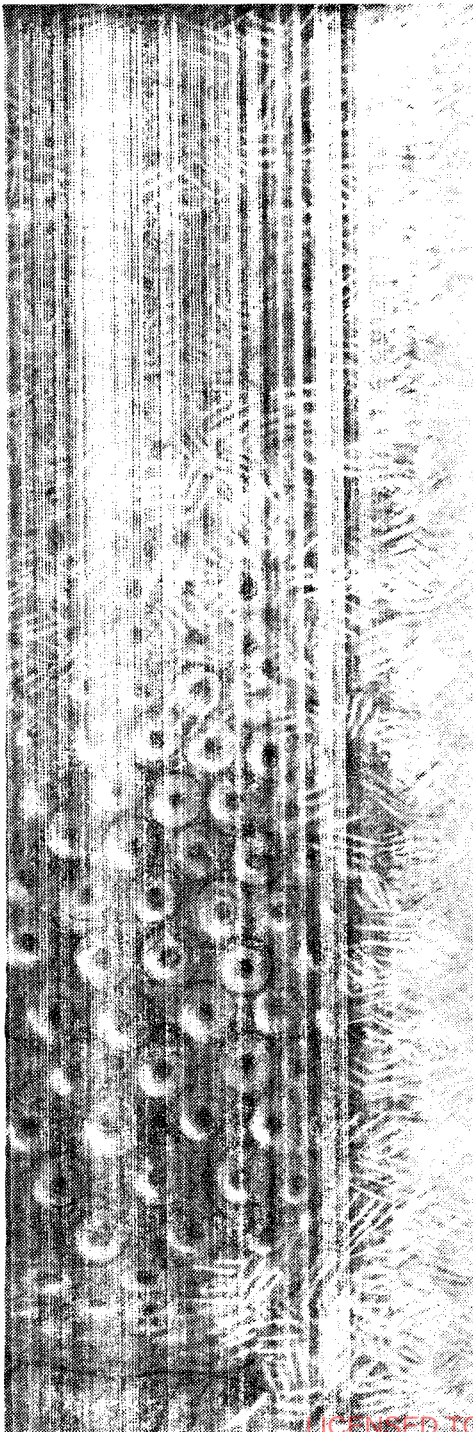

A HOG ON ICE

Rob Chilson
and
William F. Wu

"Big" means "power,"
but it also means "inertia."
A big institution
may be slow to recognize
all the implications
of a major innovation. . . .

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Chase Li reached for the door handle of the car to get out the moment it stopped moving, but hesitated when Randall Derek leaned back from the controls with a sigh.

"What is it?" Chase asked. He despised this duty, but wanted to get it over with.

"I just want to remind you that I'm going to Jeff City to do the same damn thing you are here, the moment I let you off. And remember, today we're just giving warnings and making appraisals. The kill is still a month away."

"That's very small comfort, Randall. I'd just as soon be drowning puppies. I was with St. Louis Area Registered Phone Company when we were the pup."

"And you left to go into business for yourself a long time ago, when the business was booming. Have you forgotten that SLARP is still only a combine of about twenty small companies? It's called competition, *Mister* Li. Maybe you've heard of it?"

Chase's jaw tightened at Randall's tone, but he said nothing.

"Either this local pup, Kirkwood Registered Phone, is going to sell out and join us or it's going under. You make sure they know it. Big money from Bell is moving in on SLARP, pressuring me. That's why I hired you on as a consultant."

"So your own subordinates wouldn't have to do the dirty work."

Randall's eyes narrowed. "Like I said—you handle this right, I'll take you back on board at a good salary. Then you won't have to go under as a consultant just because the boom is over." He inclined his head toward the building to their right. "I'll be back for you at 5:00 this evening."

That job was his only prospect at the moment. Chase got out and walked toward the small building out in the rural Missouri woods as the car departed behind him. The small structure was fairly new, but made of an inexpensive prefab foam and veneer material. He remembered when SLARP had been housed similarly. Kirkwood Registered Phone was just one of hundreds of small companies formed after deregulation to gobble up the local practice. They were all now trying to be as independent as a hog on ice, in a declining market and in the face of ruthless combines like St. Louis Area Registered Phone.

He pushed open the outer door and walked down a short hallway. Ahead of him, he heard a woman's voice saying, "Excuse me, gentlemen. A car just took off outside, and I believe our big appointment for the day has arrived."

"You mean the hatchetman," said a man's voice. "Come to call in Bell's note. That'll just about finish us."

Chase straightened just a little, determined to pretend he had not heard, as he entered the interior doorway. The man who had spoken was gone now, but a strikingly attractive blond receptionist smiled pleasantly at her desk. Then the smile faltered a little.

"May I help you?" she asked.

"I'm Chase Li, of SLARP." He waited patiently for her response.

"*You're* Charles E. Lee?"

"Yes." He looked at her, deadpan. "I was married in a grey tuxedo, but I am not descended from any Civil War general. The Chinese were scarce in that war."

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She still hesitated uncertainly, so he grinned to let her off the hook.

"I see. Please come with me." She opened the door to an office and peeked inside. "Mr. Cannon, Mr. Li is here from SLARP." She pushed the door open wider and held it for Chase.

Inside, a well-fed man with a fleshy face and balding head was quickly shoving some model train cars into his desk drawer. He looked up uneasily, his nervousness in strong counterpoint to the conservative, three-piece navy blue suit he wore. On the wall behind him, a giant stuffed pike glared down at Chase.

The receptionist left, closing the door behind her. Chase turned to find a younger man also in the office, extending his hand in greeting.

"Mr. Li. I'm Gene Crockett, in charge of the technical staff and liaison with the business side." He was probably in his twenties, wearing a western shirt and jeans, more common in the Registered independents than business suits.

"Pleased to meet you, Mr. Crockett." Chase smiled at his earnestness and the way he had described his role here. Two years ago, Chase had had a similar role at SLARP, and he knew just how vaguely defined job descriptions could be on a small staff. Chase's only question now was how they would try to keep the axe he wielded from falling.

"Call me Gene, please."

"All right, Gene. I'm Chase." This would be easier if he could put them all at ease.

Gene registered pleasant surprise at the reciprocal informality, but he said nothing.

Chase turned to Mr. Cannon. "So you're a modelist, too."

"Uh—I—too? You collect trains?"

"No, tractors." Chase offered his hand.

Mr. Cannon took it slowly, but firmly. "T—Tractors? Say, you're all right." He looked at Gene with a nod. "He collects model tractors. Chase, is it? I'm Adrian."

"Not only model tractors. Real ones, too. My family are farmers, from back when there were still family farms. Now they run a dude farm, and we have a collection of genuine antique tractors, some of them fifty years old."

"No kidding. Real tractors?"

"My model tractors come mostly from toy stores, I'm afraid, but a few are serious models. I have almost thirty replicas, and it's taken me ten years to collect them."

"Is that right. Say, these train cars aren't too cheap, either—"

Gene cleared his throat. "Fascinating, Mr. Cannon, but perhaps this isn't the time."

"Well." Chase sighed. "Granted, my purpose here is not a happy one. We all know that. Frankly, while Bell was in the forefront of the drive to deregulate local phone service, it has come to regret that. Please don't quote me on this. They didn't foresee the neutrino beam, which eliminated satellite and microwave relays. For that matter, it's mainly Congress that has preserved the big companies as long-distance carriers. You could link your board to any local in the nation without much trouble, if it wasn't illegal. Who needs Ma Bell? Combines of independents, like St. Louis Area Registered Phone, could do

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all they do, if Ma Bell hadn't moved in and financed them from the beginning.

"Anyway, you see why they're playing rough. Prices are up all over. I have a list here: parts, supplies, repairs, and of course long distance, which you have to pass on to your customers. To put it crudely, they're putting the pressure on, and it's filtering all the way—" He stopped, belatedly aware that he was ignoring tact in favor of brevity.

"All the way down to the bottom," Gene finished. "Like us."

Chase nodded reluctantly. "Crudely, again, the choice is bankruptcy or joining us."

There was an awkward silence.

"Gene," said Adrian pointedly. "Weren't you going to show him around a little?"

"That's right!" Gene declared heartily. "Mr. Li—Chase—please allow me to show you what our facility here is like."

Chase suppressed a wistful smile. So that was the only gimmick they had—to show him how dedicated and efficient they all were. Bell wouldn't care, so Randall wouldn't care . . . so Chase couldn't afford to care. He shrugged anyway. "Sure, I'd be glad to see your place." It would only buy them a few minutes.

"I want to show you the back room."

The back room was the silent heart of the phone company: the four-meter long Main Board, a state of the art multiplex neutrino beamcaster. It could handle ten thousand two-way beams, each focused on a given spot no bigger than a dime at many miles of distance.

Chase's experienced eye recognized the board as one of the newest and best and most expensive, one source of the company's problem. He and Gene paused for a moment, in awe of this sleek piece of super-science despite their familiarity with it. The neutrino beams that carried audio, video, print, and other communications media penetrated air, soil, stone, and the heaviest metals with equal ease. The only thing that stopped them was the energy-dense force fields within the transmitter-receiver antennas. This penetrating quality eliminated all wiring except within the house, from the transceiver antennas to the phones themselves. The transceivers were about the size of a footlocker and took little power.

"I read an article in a trade journal recently, and I think we can improve on our efficiency here. Mr. Cannon will be sending in our techs to meet you in just a moment."

Chase nodded noncommittally.

"What we want is tighter definition of the beams," said Gene. "Even at dime size, when you have ten thousand of them coming into a single antenna, they're tightly bunched. This thing's twelve feet long and it's jammed full of electronics—mostly computer boards. These are the switchboard connectors, the call tracers, the billing devices, and so on. The actual working hearts of the system are behind."

"The beamcast ring and the receiver antenna sphere," said Chase.

"Right." Gene opened three hatches like automobile hoods in the board. One stuck when he attempted to unlock it and he kicked it till it surrendered.

At one end of the board was the unmistakable beamcast ring, looking like a horizontal wreath a meter and a half

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in diameter, made of four tiers of blunderbusses with their barrels pointed out. The sparse top tier was aimed a little above the horizon, the second two roughly at it, and the bottom tier just below it. A smaller ring of half a dozen blunderbusses were motor-driven; they were the aiming beams, that sought out new transceivers and locked on to them.

At the other end of the board was the receiver sphere. It was a glassy or porcelain-seeming ball less than a meter and a half in diameter, which looked mirror-plated around its horizontal equator, where the beams were active. At the top of the ball was a braid of conductors taking power inside the hollow sphere to feed energy to the surface. The threads that carried out information in the form of signals were almost lost in the maze of power wiring.

Two men came in behind Gene and Chase. One was a short, haggard man with a stubbly beard who looked as though he had neither bathed nor brushed his shaggy hair in a week. The other was a tall, slender black man.

Gene turned to make way for them. "This is Chase Li, from SLARP. I'm just showing him around. Chase, this is James Carvel, known as Doc—"

"What's the delay?" the shorter man demanded. "Still sharpening your axe?"

Gene got in his way and eased him aside.

"I'm Linus Gordon," said the black man, with a stiff nod.

Chase suspected that, as usual, the driving force behind this small company was its staff of scientific and technical types, often the brightest people in the company, but likely to be eccentric and irreverent, as well. They might be tactless to a hatchetman, but rarely dishonest.

Gene poked the antenna. "Here's what we've been talking about, Chase. This thing's more than twice as big as it needs to be, because although it's got the area to receive twenty-five thousand beams, each about a centimeter in diameter, it only has room for about ten thousand around the equator. You see, we don't have customers in the air above, or in China. Our customers mostly live on the horizon. Most people bury their transceivers in the basement where they won't be subject to vibration."

"That means that things get jammed around the sides of the sphere," said Doc. "Right, but so what? Aren't we big enough to allow for that? Sucker's *designed* for ten thousand beams, isn't it?"

"Yeah, but look." Gene rocked back on his heels and looked up at them. "With the new technology, we don't need one-centimeter reception. Most of the beam-circle area is used for redundancy, to see if the beams are drifting. If we can reduce to half-centimeter, we can increase our capacity to forty thousand."

"How about the beamers?" Linus asked. "Can we quadruple their capacity too?"

"Oh, yeah, that's actually quite simple. The actual beams are hair-fine. Decreasing the size just means decreasing the redundancy. The need for that was overestimated in the original design."

"Quadrupling our capacity for free is not bad, Gene," said Linus admiringly.

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"Yeah," said Doc cynically. "Then we wouldn't be at forty percent of capacity, as we are now. We'd be at ten percent."

Gene looked Chase in the eye. "We'd be in a position to take on the clients from phone companies that fail. We *aren't in a position to invest in more* capacity. This might make the difference."

"Assuming we live that long," Doc growled, but said nothing more.

Gene nodded. "You two analyze that article I gave you and get back to me."

"A little late, isn't it, Crockett?" Doc pushed past him to leave the room.

"It isn't going to be a technical trick that'll save us from the big mama," Linus muttered, following him.

Chase fixed Gene with a firm look. "I'm impressed with you and your staff . . . but it's time to discuss your business affairs."

Chase sat in an old wheeled swivel chair across the desk from a very pretty young woman named Sharon. The room was a bullpen office with several other desks, though they were all deserted at the moment. Sharon's rich, shoulder-length brown hair swayed as she turned to Gene, who was leaning back dejectedly in a chair off to one side.

"Does he really have a right to hear all this?" she demanded.

Gene nodded. "Tell him whatever he asks, Sharon."

"Well . . ." She brightened and looked up at Chase. "We made a profit last month."

"Really?" Chase felt a cautious wave of relief. He was pulling for this bunch, in spite of his duty. "How much?"

"One and a half percent." She smiled weakly.

"But that's profit, not loss," Gene said eagerly. "We're on the upswing. I know it."

"What accounted for it?" Chase asked.

She wrinkled her nose. "That was the month we renegotiated our loan, so the interest went down a little. Also, Doc and Al—our sales manager—had used up all their sick and annual leave, so when they got the flu, they went on leave without pay."

Gene rubbed his forehead with one hand, covering his eyes.

Chase looked at him sympathetically, but said nothing.

"We haven't increased our overall income in six months," Sharon admitted. "On the average, we get a cancellation for every new order."

"We have to offer more services," said a man's voice.

Chase turned to see a small balding man in a bow tie leaning into the room from the doorway. He was holding a large paper airplane.

"We can't cut our rates and have any hope of making a profit, and we can't raise our rates without being undercut," the man continued, stabbing the paper airplane into the air for emphasis. "So we must offer more for the money."

Gene was on his feet and escorting the visitor out the door. "Not now, Wesley. And give me that thing, will you?" He snatched the airplane away. "Sharon, would you come with me for a moment? Chase, excuse us."

"Sure." Chase grinned at the paper airplane Gene was now crumpling behind his back. He almost made a teasing

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comment about it, but was afraid any joke would be taken wrong coming from a hatchetman.

Chase sat alone in the room, his arms folded, leaning back in the swivel chair. He didn't know much about the business or technical abilities of the people in this company, but he recognized a strong rapport among them. It wasn't obvious, but subtle, and all the more genuine for that. It could only be based on mutual respect, and that implied the technical and business ability that he couldn't read on the surface.

He became aware, slowly, of voices spoken at low volume right in front of him. The sound was coming from Sharon's desk. He looked over the desk for a moment, then realized that the sound was coming from the speaker phone. Some connection had been left open.

Chase glanced at the door, which was closed. He would never have deliberately spied on them, nor was he actively doing so now. Still, as long as he was just sitting here, anyway . . .

"Wesley is right," Sharon was saying. "We must offer more for the money. And Al is right, too. The market is saturated, and our only chance is to hang on and out last the other small companies."

"Whoever dies with the most toys, wins," said another man's voice, apparently Al's. "In this case, the company that lives the longest."

"Winner take all," said Sharon.

Someone slapped a desktop. "I've been in phone service all my life," said Al. "I said when they were totally deregulated that no good could come of it. I told you all that. No good will come of it. I told you so."

"How bad is it, Gene?" Sharon asked.

"They want to buy us out. Here's the new list of prices Li gave me. If we don't sell within thirty days, we'll be forced out by rate hikes and price increases for the parts, other supplies, and long distance services we buy from Bell. After all, big phone companies *are* the cheapest source for most things."

"Wait a minute," said Al. "Wait just a minute. How does this affect me?"

"Don't despair, Al," said Sharon. "All you have to do is give us a fifty percent sales increase to enable us to stagger on as we are under this new price list."

Al groaned.

"Gene?" Wesley said. "Did you show him the Main Board and explain the changes you want to make?"

"Yes, Wesley, but I don't think he realizes what it could mean. We'll have more capacity for the equipment than any company our size. And anyway, it's probably just too late. We only have a month to agree to join them. If we don't agree, they bankrupt us with the new rates."

"Gene, what about the FCC?" Sharon asked. "Doesn't it look with disfavor on one big company buying out all these little ones? They broke up all the old monopolies."

"Yes and no. If a big company can show it doesn't have an actual monopoly in a given market, the FCC won't stop them from becoming the elephant in the goat herd."

"Do you think Mr. Cannon will sell?" Wesley asked.

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"I don't know," said Sharon. "He might just go out of business instead, out of spite."

"Good for him," said Wesley.

"I feel much that way myself," said Gene. "Come on, let's break this up. I have to get back out there."

Chase grinned at their stubbornness. As to what those changes in the Main Board could mean, well, Chase knew this business, too. The real question was how this little shop could make a major turnaround virtually overnight. He didn't have a solution for that any more than they did.

By the time Gene came back in, alone, Chase was leaning back in the chair and gazing at the far wall.

"Sorry about leaving you so long," Gene said cheerfully. "As I understand the situation, we have thirty days to give SLARP an answer. We would like to utilize those thirty days, and have you contact us again at that time. I . . . don't need to ask for your appraisal of us."

"Fine." Chase hesitated. "I must tell you about a new problem in our field. I expect a new law to be passed governing it once the phone lobby gets moving." He turned at a sound behind him, and found Doc entering the room and heading for a coffee stand. "Some of our business clients have taken to buying two phone transceivers and hooking them together, each focused on a different exchange company. That way they pay two phone bills, but they can talk to their out-of-town units—head office to branch office, say—without paying long distance rates."

"Explain that further," said Gene, looking startled.

"Don't spread this around," Chase warned him, sweating a little. "The big companies don't want too many people to know about it until they can get it outlawed. But it's simple to buy two transceivers, then contract with two different Registered phone companies, one to service each transceiver. One phone company in each of two cities, do you see? By itself, that isn't illegal, but connecting them together circumvents the law on long distance relays. It's a legal loophole, and if business pushed it, they might get it protected. So the big companies want it outlawed."

"Is it cheaper?" Gene asked, cocking his head.

"Probably not for a private user, but for a business that's constantly in touch, and sends lots of computer data, even a small long distance charge would mount up. Anyway, if you see evidence of such a hookup, you are to report it."

"Report it?" Doc demanded. "Great. Now I'm a phone cop." He left the room, shaking his head disgustedly.

The rest of Chase's visit was taken up with Sharon's computer records of the company's finances. As near as he could tell, the company had been run honestly and intelligently. Even now, it was making enough money to keep going for a year or so, except for the pressure from Bell filtering down through SLARP.

Randall arrived on time, and got to the point as soon as Chase had slammed the car door shut.

"I got an order in over the radio while I was on my way to Jeff City," said Randall. "SLARP is under a hiring freeze."

"What? For how long?" Chase de-

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manded, his stomach dropping as the car accelerated.

"Indefinitely," Randall snapped.

"I've done everything you asked—"

"Forget it, Chase. My hands are tied. SLARP isn't the big fish in this pond, remember; it's only the middle one. The best I can give you is to let you finish out the month on this current contract with us as a consultant. Then, someday in the future . . ." He trailed off.

Chase clenched his jaw angrily and stared straight ahead.

Early the next morning, Sharon blinked with mild surprise as Doc arose from behind the couch in the bullpen office like Triton arising from the wine-dark sea, blinking sleepily.

"I did find one interesting thing last night," said Doc. He steadied himself on the back of the sofa and hand-walked along behind it until he reached the end, then fell over backward onto it. "I checked it out because of something our hatchetman told Gene.One of our customers does have a second phone transceiver. It was set on a local in London. They weren't connected together or anything, so it wouldn't even violate that law Gene says the phone companies are going to get passed."

"On *London?*" Sharon said.

Doc looked at her vaguely. "Yeah, why?"

"Well, I—I didn't realize phones had that much range." Sharon laughed nervously. Solicitously she brought him coffee in his labeled mug. Doc performed the curious feat of drinking out of his mug while lying on his back, with the dexterity of long practice.

"As Gene says, it's cheaper than long distance rates," said Wesley, from his own desk. He threw a folded paper missile with a paperclip warhead toward Al, who was flipping cards down into a solitaire pattern on his desk.

It glanced off Al's ear. Al, a small man wearing a suit that looked as if it had been ripped off an automobile seat, ducked and shrugged angrily but otherwise pretended not to notice.

"Yeah. But what it means is that fees that the long-distance companies and we would normally get are all going as local fees to London instead." Doc winced at the heat of the coffee.

"If we had any luck we'd get in on that," said Al, observing out of the corner of his eye Wesley's new weapon. It was being made of a sheet of heavy construction paper two feet long.

"The last time this company had any luck was when Gene got fired from that job in Phoenix and came east," Doc said, and with an angry grunt he shifted to a slightly more upright position.

"If we had a sales director who was worth his salary, or half of it," said Wesley, "we *would* get in on that kind of thing."

Al, throwing dignity to the wind, ducked his head and wrapped his arms around it in classic air-raid stance. The massive missile plowed instead through his solitaire array. Giving up, he seized the first small airplane that came to hand and hurled it back, missing, then threw the big one, and missed again.

"This hard-luck company couldn't make money if it was raining money," said Al. "Nobody even in London would do business with us; they'd be crazy to."

"Wesley," said Sharon suddenly.

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"That weather service of yours—you designed it to call people's phones and leave a message on the recorder without their having to call and ask, didn't you?"

"Why, yes." Wesley pushed his glasses back up on his nose, and folded another piece of paper. "It's interactive, too; they can call and ask for specific bits of information, or weather elsewhere."

Wesley hit home with his next airplane, and Al's own next throw simultaneously looped back and also hit him.

"Five to three Wesley scores more hits than Al," said Doc dispassionately. "Al's hits on himself don't count either way." He glanced at Sharon.

Sharon, sitting casually on the arm of the sofa and looking toward the dogfight, was not seeing it. She was not seeing anything that anyone else there could see. After a moment, unnoticed by the others, she slipped out of the room.

Sharon found Linus sitting in the back room with the Main Board, away from the distractions of the inner office, studying physics and eyeing the trouble line phone.

"Where's Buck?" Sharon asked him.

Linus looked around with a start.

"Sorry," said Sharon.

"That's all right. Buck's out on a call. Is Doc awake—I mean, is Doc here?"

"Yes, he's awake and drinking coffee. He needs to eat some breakfast, but he'll be okay."

"That's good. What's on your mind, little mama?"

Sharon smiled. "Tell me, is it possible to set a phone on a board as far away as England?"

"Whoa, wait a minute. You don't set a phone on a Main Board. You set the Main on the phone. You have to know where to find the phone—the general geographic location—then you instruct the computer to generate a search pulse from one of the beam casters pointed in that general direction. The search pulse flares out, see. It gets an echo—an enhanced echo—from the phone, repeating the number the Main had previously assigned to it, and which has been keyed into the phone. Got it?"

"I think so," she said, sounding doubtful. "So there's really no limit to how far you can transmit and receive calls."

"No practical limit Doc and I have been able to find. I see no reason why we couldn't access a phone in China."

"I see. Tell me, Linus, why is the receiving antenna in the Main a sphere? Sixty percent of it is unused."

"It has something to do with the natural shape force fields take in space. The antenna is constructed to present solid matter just at the point of maximum energy density. That increases the density by a factor of seven or eight. Physics allows for holes in the sphere, but the general shape must be spherical."

"And it's easier to get at the sphere from the top, so that's where the power and communication lines enter. The bottom is unbroken—right?"

"Yes. Why?"

She smiled mysteriously at him. "Come with me, Linus."

"Now that's an invitation that's impossible to refuse." He rose, curious.

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She reddened. "That's not what I meant—"

One month later, Chase walked into the front office of Kirkwood Regional Phone and found Gene Crockett and Adrian Cannon waiting for him by the receptionist's desk with big smiles.

"Hello, Chase," said Adrian pleasantly. "Eugene, would you do the honors?"

"Of course." Gene handed Chase a slip of paper.

Chase looked down at the check and raised his eyebrows. "This—"

"Is the full amount of our note with SLARP," said Cannon proudly.

Chase laughed in pleasant shock. "I certainly never expected this." He winked at Adrian. "I think I'm going to like giving this to my boss. He won't enjoy it at all."

"Gene here tells me that we are now free to disassociate ourselves from SLARP, under our agreement with them."

"That would be customary," said Chase. "But, uh, would you mind telling me—"

"How we did it?" Gene put his arm around Chase. "Come on, I'll show you. Elizabeth, notify Sharon that we're coming back to see her."

Once again, the bullpen had been abandoned so that Sharon could show Chase her computer records without distraction.

"Basically, it's very simple in business terms," she said, with a shy smile. "I thought we could expand our base of customers by advertising for them in other markets."

"Customers?" Chase asked.

"Yes. Residential or business, preferably the former; they'd be easier to reach."

"What other markets?"

"Taiwan, or the Philippines; Vietnam. Australia would be good."

Off to the side, Gene was grinning with smug pride in her.

"You see, the bottom half of the receiver is unused, so people on the other side of the world would be our best bet. And since we've quadrupled our capacity, we could take on quite a lot." She looked at Chase and shrugged.

"How did you reach these potential customers?"

"Called them on the phone," she said, looking down.

"Right," said Gene, to Chase's startled glance. "Wesley already had a program for calling large numbers of people with a recorded message; with interactive programming and the computer system we already had, it was a snap to get the name and address of anyone who was interested. Of course there are only nine thousand nine hundred ninety-nine numbers in our four-digit assignment, but we can easily code nine thousand nine hundred and ninety-nine times as many—close to a hundred million if we need 'em."

Chase was grinning fatuously himself, close to giggling insanely.

"We've picked up over a thousand new clients in Australia," Gene said mildly.

"Australia? Why Australia?"

"They speak better English there than most places on the other side of the world," said Gene.

"Not by much," said Linus, coming through the doorway.

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"The beer is good, though," said Doc, right behind him. He winked, and the two techs walked through the office and out the opposite door.

"So—you have *local customers* in Australia." Chase looked back and forth between Gene and Sharon. "And if they call someone next door who is not one of your customers—"

"We have to go through a local exchange. But there are books full of exchange listings," said Gene. "The distinction between local and long distance has faded since the introduction of the neutrino beam. That's why the big phone companies are so anxious to suppress the locals."

Chase nodded at that. "You don't charge for long distance in such cases?"

"Only in America," said Gene, "and then only because it's the law. We have ceased to charge for long distance for all other clients. Where it's an Australian client, I doubt that American law could be enforced."

Chase nodded again. "I doubt that law will survive long," he said, controlling himself with an effort. Then he had a thought. "How can you possibly reach all the different exchanges that might be needed in a world-wide operation?"

Gene looked at Sharon.

"That's with the new equipment we ordered," she said, failing to stifle a smile.

"A hundred motor beamcast units," said Gene, "which Doc and Linus fastened to a frame like half a ball-shaped flower, pointing down toward China. These units are the same kind that are used for ordinary long-distance calls—you don't think phone companies maintain any number of beams fixed on distant targets, do you? We have always used the same echo-and-response technique for locating other Main Boards."

"So, essentially," said Chase, a wild surmise lighting his eyes, "even the longest long-distance call need go through no more than two exchanges. Why, it would only take a couple of seconds! The big companies really let their skimmers leak when they deregulated and expected to make their money selling or leasing neutrino equipment."

"Yeah." Gene folded his arms and eyed him carefully. "But I've taken quite a risk explaining this to you. The question is, what are you going to do about it?"

"Do?"

"As an official of SLARP, ultimately representing Bell Telephone. If that law you told me about is going to be passed . . ."

Chase accepted coffee from Sharon and smiled. "Oh, but I'm not an official of SLARP."

Gene sat up sharply. "What?"

Sharon stared.

"I'm an independent consultant, contracted to handle some cases like yours for SLARP. My time is up this week. Taking your check to my current boss will be my last official act."

"No kidding," Gene muttered, smiling at him.

"Maybe you should know, Mr. Li," said Sharon. "I got the idea because of something Doc said. He told us about someone using double transceivers, but he only checked for it because you told him it was happening. I worked out the details with Linus, but we actually used you as the springboard."

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Chase laughed aloud, finally. "Maybe you two should know. I leaked that little bit of information because I've been thinking someone could make use of it ever since I first heard it."

Gene and Sharon exchanged glances.

"Wait a minute," said Gene. "Are you trying to say you *knew* we would do this?"

"No, not at all." Chase shook his head, still laughing at their expressions of astonishment. "It did occur to me that the . . . I don't know, the rapport and skill you folks have here might help you make something of the raw data. I'm not closely involved with the technical side, anymore, and I didn't see how to use it." He nodded at Sharon, across the desk. "Obviously, you did."

"You set us up," said Sharon, putting a dainty hand over her smile at Gene.

Chase cleared his throat. "I, uh, got the impression, shall we say, that you knew you had something special with those changes in the Main Board you were proposing, even if you weren't sure what. That encouraged me to leak the idea of the two transceivers."

Gene ran a hand through his full head of hair. "Shall we tell him?"

Sharon laughed. "I think we better. Chase, did you really think a couple of telephone executives would accidentally leave a speaker on with a hatchetman —excuse my language—in the room?"

"Uh—" It was Chase's turn to stare at her.

She and Gene both laughed.

"Let's just say," said Gene, "that I was leaking a little information myself. You seemed interested in the Main Board's new potential. I wanted to make sure you knew that we had some kind of hopes for it, even though they were vague. I didn't know if it would help, but I figured it couldn't hurt." He shrugged. "You seemed like a decent guy. I was hoping you'd feel some sympathy when you overheard how dedicated everyone was, even when you weren't in the room."

Chase shook his head at the irony. "It worked out, all right."

Sharon folded her hands on her desk. "Chase. How is the consultant business going?"

He shrugged slightly. "I'm getting a lot of competition. Jobs in the communications industry are at hazard at the moment, and the biggest companies are the worst off. AT&T is on its last legs, and ITT is not far from bankruptcy, either." He looked at them. "Gene, I think you just killed them."

They were astonished. "Oh, come, with all their money and power? I hardly think a simple technical innovation—"

Chase shook his head, dead serious. "Remember how many people it once took to keep up the wires and handle the records?"

They nodded.

"This trend is happening all over. Mining, for instance. Once it took thousands of men to dig in the earth for metals. Now a couple of dozen man the pumps of a seawater refinery. Or manufacturing, now almost wholly in the hands of robots. Or farming. The technological trend has always been to eliminate human labor. Everywhere, large organizations are being replaced by small concerns as independent as a hog on ice, where no one wears suits; because the kind of thinking that would

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impose suit-wearing conformity doesn't deal well with massive change. Well, massive change has been happening to the phone companies."

Chase looked at Gene, who nodded, clearly not believing. He'd learn. Within a year or two—

Gene cleared his throat sympathetically. "In other words, it's not going too well for you."

Chase shrugged. Idly, he slipped a piece of paper from Sharon's desk and started working it nervously. "A consulting service doesn't require strict credentials. A lot of out-of-work types are trying it."

"To be honest, Chase, we aren't entirely out of the woods yet. All we did was use our financial upswing to get a new loan from a bank. They agreed that we'd make a better investment if we were free of SLARP. We didn't get all that money as income in just thirty days." Gene nodded toward the check, now safely in Chase's wallet.

"We're expanding fast," said Sharon. "Most of the new client hook-ups are handled by the computer, but . . ."

"We're going to run up against SLARP and Bell more often every day," said Gene. "We need someone who understands them to come on board. Unless you feel a loyalty to them, of course . . ."

For an answer, Chase lifted his paper airplane and threw it into Gene's face. ■

IN TIMES TO COME

Last month my editorial dealt with the far-reaching implications of nanotechnology, the embryonic art of building almost anything atom by atom—embryonic now, that is, but promising/threatening to develop explosively over the next few decades. In that editorial I highly recommended K. Eric Drexler's book *Engines of Creation*—and next month our fact article is an introduction to nanotechnology written expressly for *Analog* by K. Eric Drexler and Chris Peterson. In the space available, it can't tell you everything the book does, of course, but it can and will give you a good idea of just how startling the potentials and dangers are. And I strongly suspect it will whet your appetite to read more on the subject.

The cover story is Harry Turtledove's novelette "Last Favor," wherein human visitors are confronted by two groups of aliens sharing a planet and a decidedly peculiar relationship. One side obviously needs help—but what do you do when your idea of what constitutes help is radically different from that of the people you're helping?

We'll also have a "State of the Art" piece by L. Sprague de Camp on the early days of science fiction movies, plus a highly diverse collection of stories by Ian Stewart, D. C. Poyer, and Gregory Kusnick. And, of course, Part II of Lois McMaster Bujold's *Falling Free*.

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a calendar of analog upcoming events

December is a quiet month for conventions with people heading home for the holidays, so I've spread out a bit into late November and early January.

20-22 November
SMOFCON IV (Convention for convention organizers and managers) at Quality Inn, Columbus, Ohio. Registration $35. The emphasis and theme of this con will be "Regional Conventions." Info: FANACO, Inc., c/o Liz Gross, 376 Colonial Avenue, Worthington OH 43085.

27-29 November
LOSCON XIV (Los Angeles area SF conference) at Hilton Hotel, Pasadena, Calif. Guest of Honor—C.J. Cherryh. Fan Guest of Honor—Tom Whitmore. Registration—$15 until July 1987. Info: LASFS, 11513 Burbank Blvd, North Hollywood CA 91061. (818)760-9234.

27-29 November
DARKOVER GRAND COUNCIL MEETING 10 (SF conference oriented to works of Marion Zimmer Bradley and writers of similar fiction, feminism, and the occult) at Radisson Hotel, Wilmington, Del. Info: Darkover Grand Council Meeting, Box 8113, Silver Spring MD 20907.

4-6 December
TROPICON VI (south Florida SF conference) at Holiday Inn Oceanside, Fort Lauderdale, Fla. Guest of Honor—George R.R. Martin, Artist Guest of Honor—Gail Bennett. Registration—$12 until 31 October 1987, $15 thereafter; bufffet banquet $19. Checks payable to S. Florida SF Society: SFSFS Treasurer, 4427 Royal Palm Avenue, Miami Beach FL 33140. Info: Tropicon VI, Box 70143, Fort Lauderdale FL 33307.

1-3 January 1988
EVECON (Washington D.C. area SF conference). Info: Evecon, Box 128, Aberdeen MD 21001. (301)422-1235.

15-17 January 1988
CHATTACON XIII (Tennessee area SF conference) at Holiday Inn/Convention Trade Center, Chattanooga, Tenn. Artist Guest of Honor—Frank Kelly Freas, Fan Guest of Honor—Maurine Doris, Fan Artist Guest of Honor—Kevin Ward, TM—Charles Grant, Special Guest—John Steakly. Registration—$15 until 1 December 1987, $20 at the door. Info: Chattacon, Box 1632, Chattanooga TN 37401.

1-5 September 1988
NOLACON II (46th World Science Fiction Convention) at Sheraton Hotel & Towers, Marriott Hotel, Rivergate Convention Center, New Orleans, La. Guest of Honor—Donald A. Wollheim, Fan Guest of Honor—Roger Sims, TM—Mike Resnick. Registration—Attending $60 until 31 December 1987, $70 to 10 July 1988. Supporting—$30. This is the SF universe's annual get-together. Professionals and readers from all over the world will be in attendance. Talks, panels, films, fancy dress competition, the works. Join now and get to nominate and vote for the Hugo awards and the John W. Campbell Award for Best New Writer. Info: Nolacon II, 921 Canal Street #831, New Orleans LA 70112 (504)525-6008.

—Anthony Lewis

Items for the Calendar should be sent to the Editorial Offices six months in advance of the event.

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RETROGRADE ANALYSIS

William Ballard

Usually, the sooner a problem can be solved, the better.

But not always . . .

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Emanuel Lasker slouched in a worn wing chair, chewing on an unlit cigar and tapping the rug with a slippered foot, and eyed with genial skepticism the little box he held in his lap. It was made of some smooth manufactured substance imbued with a false wood grain: set flush into its top was a dark green glass square as big as the palm of his hand, and rows of push buttons labeled with numerals, letters, English words.

In Lasker's smoking jacket pocket was a note, stilted German scrawled in a plain American hand. He had read it several times since its arrival four hours earlier, and by now had it almost by heart:

"Dear Doctor Lasker: I am an assistant professor of physics at Columbia University in New York, and have just arrived in Berlin. Before you leave for Havana, I'd like to show you something remarkable—a machine that plays master-level chess. I would greatly value the World Champion's opinion of its play, and, further, would consider it an honor to make the acquaintance of the author of such fine treatises on mathematics and philosophy. May I call on you tonight at eleven? Please give your reply to this messenger. Sincerest regards, Roger Carey."

He smiled wryly as he remembered the cool reception Carey's note, and his own assenting reply, had received at the Lasker household. His witty and animated wife, usually gracious to the most eccentric of his chess cronies, had pointedly retired for the night at 10:30. Nor had their old friend Ossip Bernstein, who had been present when the note arrived, been curious to meet its writer. "A crackbrain," the emigré Russian grandmaster had said. "A chess-playing machine, indeed! Send this boy back with an emphatic 'no,' put such nonsense out of your head, and prepare yourself to meet the Cuban. If you don't, you're crazier than this Carey."

And now, seeing the machine, Lasker was inclined to think Bernstein was right. For all Carey's double-talk of "macromolecular processors," "iterant search-plies," "pruning algorithms," and "killer/capture heuristics," common sense told Lasker that even if a chess-playing clockwork could be designed, it would have to be the size of Berlin to play a rational game, let alone a masterly one.

Perhaps he had agreed to see Carey out of curiosity to meet an American who knew of his non-chess writings. If the man proved to be demented, his visit would still make an amusing story. Lasker had imagined a wizened, untidy savant with untrimmed white beard and rheumy eyes, trundling something vaguely the size and shape of a pipe organ up to his door.

He twisted in his chair to look at his visitor, thinking how wrong that mental picture had been. The dapper American was brown-haired, rosy-cheeked, clear of eye. He had explained the operation of the chess-box in a soft-edged voice that bore traces of the American South, then had walked to the bookcase, pulled out the Schlegel-Tieck translation of Shakespeare, and seated himself over by the fire.

At fifty-two, Emanuel Lasker was a man of wide experience. Chess grandmaster, world-class bridge player, and one of the first Occidental devotees of

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go, he was also a theoretical algebraist, had dabbled in farming and business, and had written such ambitious philosophical texts as *Die Philosophie des Unvollendbar* and *Das Begreifen der Welt*. In everything he did, he tried to avoid preconceptions and slavish reliance on authority. Original thinkers in many fields frequented his home, among them Albert Einstein, who often argued mathematics with Lasker from the very chair in which Roger Carey now sat.

But even Lasker's open-mindedness had been tested when Carey had told him that he was a traveler in time, and had brought the chess-playing machine with him from the year 2067.

In support of his claim, Carey had showed Lasker his wristwatch, which silently displayed the time to the second in ever-changing digits. He had demonstrated under a bright lamp that his conservative clothing—tweed suit, wing-collared shirt, cravat, boots, even his bulging valise—were entirely made of ersatz fabrics; synthesized, he said, from petrochemical polymers. Lasker felt sure that no one was making plastic fabrics—yet. Still, he had made a mental note not to speculate in cotton futures.

And Carey spoke German correctly but woodenly, like a classicist discoursing in a dead language. Lasker, who had spent years in England and America, had tactfully switched to English. Carey had followed suit, blaming his brittle German on—Lasker thought he had heard correctly—"a lousy job of RNA encoding."

All of which was tantalizing but not conclusive. Was Roger Carey a futurian visitant or a madman? Lasker held the answer in his hands. If this box could play chess, it was the product of a technology far beyond that of 1921. If not—well, he would ease the American out the door as gently as possible.

The test, it seemed, would be fair enough. Carey's back was turned; and, recalling the hoax chess automata of the last two centuries, Lasker had to admit that the box could hardly conceal a human operator, as had Kempelen's Turk and Hooper's Ajeeb, nor were there wires attached allowing control from a distance, as with Gümpel's Mephisto.

So the World Champion pursed his lips, smoothed his mustache with thumb and forefinger, and began.

He gingerly pressed the button marked *POWER*, half expecting to get an electric shock. Instead, the glass on top brightened into life: a luminous chessboard diagram, the pieces solid red and black, the dark squares delicately hatched blue-green. The tiny image was exquisite, brighter and sharper than that of any camera lucida Lasker had ever seen.

Silver letters were superimposed over the diagram: *SET UP A POSITION (Y/N)?* Lasker pressed the button marked *NO*, to start from the initial setup. The overlay changed to *LEVEL OF PLAY (1-12)?* He pressed *4*, which supposedly caused the machine, once the opening phase was over, to respond in two to three minutes. "It should give you a pretty good tussle if you play at the same pace," Carey had said. "It's stronger yet at higher levels, but I don't think you want to fool with it all night just to play one game." The overlay asked *DO YOU WANT WHITE (Y/N)?* Lasker

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shrugged, pushed *YES*. The overlay vanished.

Carefully Lasker punched out his first move: *D2-D4*. The notation appeared in the tiny silver script beneath the chessboard, but nothing else happened; then he remembered to push the *ENTER* key. White's queen's pawn jumped forward two squares.

The machine played its first move instantly, supposedly making a selection from a 250,000-move opening library: . . . *G8-F6*. On the diagram, the Black king's knight sprang forward into play.

The mechanism's ingenuity and silent operation were fascinating. Lasker made a few more moves, receiving a quick response each time; then looked up and cleared his throat. "Mr. Carey, does this 'computer' play original gambits? In forty years of chess, I've never seen this opening."

The American cocked his head, asked over his shoulder, "What did it play?" Lasker related the first moves. "Oh, the Benko Gambit," Carey said. "It'll be very popular for a while, fifty or sixty years from now. Amazing, isn't it? A sound pawn sacrifice by Black on only the third move."

"But how can such moves be sound? Black has given up a pawn in a position in which he has already conceded greater central space to White. God himself couldn't hold such a position against a grandmaster."

Carey smiled enigmatically. "I'm sure you'll have an interesting game," he said, and returned to his book.

Lasker peered sideways at the American. Could this, after all, be a deception? Carey was engrossed in the Shakespeare, moving his lips as he plowed through the German text. But did he have a confederate outside with a wireless set, receiving Lasker's moves from the box and sending replies back to it?

The grandmaster decided to finish off the game, showing up the weak play of his unseen opponent, then demand an unmasking. Victory was a matter of technique: play solidly, exchange off most of the pieces, win the endgame with the extra pawn. He struck a match and lit his cigar.

With its tenth move, the machine stopped its nearly instantaneous responses; thereafter, it indeed moved in a little over two minutes. According to Carey, that meant it had reached the end of this branch of its built-in opening "book" and was now having to calculate its replies.

If so, it calculated well. By his fifteenth turn, Lasker had to admit that Black had good compensation for the gambit pawn, a nagging pressure against White's left flank. Black's pieces danced; the pressure grew. By move twenty-five, he knew he was in real trouble.

He slowed down his own moves, lavishing all his skill on the position; but at last he had to submit to a tactical stroke by which Black regained the gambit pawn and emerged with much the better game.

Passive defense was hopeless. Lasker gambled all on a knight sacrifice to expose the enemy king. Black gobbled up the piece, defended coolly, broke up the assault. Black, not White, simplified into a won endgame.

Automaton one, World Champion zero.

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He sat staring at the final position for a long time, his mind locked in the grip of a terrible surmise.

The mantel clock chimed twice. Lasker was not especially tired; he liked to keep chaotic hours, eating and sleeping only when hungry or sleepy. But he was surprised to learn that he had been playing chess with the little box for two hours. His eyes were tired of staring at the little screen, his neck and shoulders stiff from hunching over it.

Squelching an impulse to seek a rematch, he switched the machine off and took it over to his guest. In courtly tones he said, "I apologize for my skepticism, sir. I was outplayed in the opening and was never allowed to recover. Even if there were a means of relaying moves to and from this box, only a great master could play so well at such a pace.

"But none of my rivals would waste so ingenious a theoretical innovation on a prank; he would save it to spring as a surprise in an important game. I conclude that this remarkable machine is a genuine product of the future—and, therefore, so are you."

Carey laid the Shakespeare down on the table at his elbow and took the computer, beaming as proudly as if he himself had won the game. "This is one of the best models ever made, manufactured in 2015," he said. "I'd like to give it to you, but we prefer not to risk the technological contamination. So back it goes to the Smithsonian." Lasker felt a covetous twinge as the gadget disappeared into Carey's bag.

He laid a fresh log on the fire, sat down opposite the American, and fished a fresh cigar and a match from his pocket. He said, "You were saying that you, ah, came back from near Canterbury?"

"Yes. Getting here geographically was more trouble than the temporal displacement. In my time, the European mainland is part of a hostile international bloc. It was impractical to displace in Havana and approach you there a few days from now, because in my time Cuba is a real mess. It's unhealthy for an unshielded person even to set foot there; taking the Chronodyne team in was out of the question."

So—the Great War, hailed by the ebullient Allies as the "war to end war," hadn't—or wouldn't, or whatever the correct tense should be. No surprise. Wars, in Lasker's view, were caused by men's stupidity, and no doubt twenty-first centurians would still be capable of behaving stupidly.

"But we're friendly enough with the English Republic. So we flew in with our equipment, and I was displaced in Kent with authentic-looking money and papers. I took passage here by boat and rail. That was really something, like watching a well-done period piece on the holo." Lasker looked blank, and Carey said, "Three-dimensional television."

" '*Tele-Vision*,' " said Lasker, frowning. "That's a bastard term from Greek and Latin. Does it refer to an optical instrument of some kind?"

Carey laughed. "In a way. It's, um, radio with pictures. Sorry; of course you don't have it yet. The historians on the Committee would give me a real ribbing if they heard me now. And speaking of them"—he consulted his futuristic timepiece—"I'll have to turn right around

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in a couple of hours, to get back in time for first retrieval." Lasker still wasn't used to seeing men wearing wristwatches; apparently the fad was going to stick.

"You've come a long way for such a short visit," said Lasker. He drew slowly on his cigar. "You spoke of equipment and a team. So I assume that this time traveling is no simple proceeding. It is costly in terms of energy, materials, manpower?"

"Also costly in terms of money. For this shot, we displaced roughly a hundred kilos fifteen decades; it took enough energy to run a small city for several hours, which isn't exactly cheap."

"Hmm. So why go to all this trouble just to come see me? Surely not to show me the chess machine; that was only to get your foot in my door and prove that you are from the future."

Carey nodded. "You're right, Doctor Lasker; it *is* high time I explained myself. Tomorrow you're leaving to play a title match with José Raúl Capablanca."

"Yes."

"I'm sorry to say, sir, that you are going to lose the match."

"Oh?" Lasker felt a pang of disappointment, which was odd. He'd long felt that his crown would someday pass to Capablanca, twenty years his junior and going from strength to strength. The match would likely be a mere formality, though a lucrative one: win or lose, Lasker would pocket $11,000 of the huge $20,000 purse. Still, anything could happen over a chessboard, and in a corner of his mind he must have nourished hopes of coming back from the New World with the money *and* the title he had held for a quarter of a century.

Carey said, "The match is set for thirty games, but you'll resign after fourteen—ten draws, four losses. You'll plead ill health and complain of the climate, but will tell the press you probably couldn't have won anyway."

Lasker sighed. "Again, you aren't here just to tell me when it will be time to quit."

"Oh, no, Doctor. I've come to help you win the match."

"I don't understand," Lasker said. "You just said I'm going to lose. If you know that, if my losing is a matter of historical fact, then surely any efforts to help me would be futile."

Carey shook his head. "It doesn't work that way. It's possible to change the past. We've done so, in a small way—at least, that's what our operatives tell us.

"It's kind of eerie. We displace our personnel, recalibrate, then make retrieval from hours or days after the drop. The returning agents often report missions similar in intent but different in detail from what we believe we've just sent them off to do. In altering the past, they've altered our present, too— including the Chronodyne Project itself. Our own memories and records have undergone a sea-change. We're still arguing about the implicit paradoxes. Since the first trials our people have carried microfilmed copies of relevant documents, for comparison with the originals after their return.

"I'm from your future, true, with all the foreknowledge that implies. But right now I share your frame of refer-

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ence." He made a sweeping gesture. "*This* is the present. I can affect the future as much as anyone alive tonight. Your match has not yet been played, ergo it can yet be won."

"But why would a man from 2067 want to change the result of a chess match in 1921?" Lasker smiled. "Unless your wealthy great-great-grandfather has wagered his entire fortune on me, and you want to go home and find yourself to be rich?"

Carey chuckled. "Very good; maybe you should be writing fantastic fiction, sir. But the truth is less romantic: We'd like you to help us carry out an experiment.

"We've learned about all we can from what we call micro-changes: burying messages, shifting small objects, leaving graffiti in wet cement. Our social scientists would like us to do something with long-term human consequences they can study—a true macrochange. But we don't dare fiddle with anything really big, like an election or a war. The effect on our own era could be catastrophic.

"Because of this impasse, the Chronodyne Project will be terminated—*unless* we can demonstrate that safe macrochanges are possible. And that's where you come in.

"I'm something of a games antiquarian. Thinking of my hobby, I proposed modifying the history of grandmaster chess. It's perfect: a rich but isolated subculture, its practical impact on larger reality almost nil. Later in this century—I'm not even sure if he's been born yet or not, as we speak—there will be a writer named Vonnegut. He'll describe chess as 'thinking that is pure as snow.' "

"Aptly put," said Lasker. "And for me how flattering, to be invited to play the role of a laboratory rat." He tapped his chest. "But why this rat? Why not some other master, some other match?"

"Well, for one thing, I'm very familiar with your exploits, Doctor Lasker. You're the greatest fighting player of all time. I convinced the Committee to let me come back myself, rather than sending a trained agent, by arguing that I was better qualified to explain the mission to you; but my real motive was that I hoped to meet you." Carey smiled shyly. "I admire you, sir. It would please me no end to help you defend your title."

"Thank you. But how on Earth could you help?"

Carey reached into his bag, pulled out a book with a red cover. He handed it to Lasker, who turned it to look at the golden letters stamped on its spine: *History of the World Chess Championship, 1843-2039*.

"Don't be afraid to open it; I razored out the biographical sketches," Carey said. "You wouldn't want to know how or when you and your contemporaries will die."

Lasker shivered; he hadn't thought of that. He was grateful that Carey had; otherwise, he might have started reading about himself, and—!

When he had recovered his aplomb, he opened the book. It had been—would be?—published in 2049. He skimmed the table of contents; the chapter headings enabled him to trace the identities of the champions.

The first few names were familiar:

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Anderssen, Staunton, Morphy, the strongest players of the mid-nineteenth century; Steinitz, first to claim the formal title, World Champion; Lasker himself, who had won it from Steinitz in 1894. Next listed was, to be sure, Capablanca.

Capablanca would be overthrown in 1927 by the brilliant but egoistic Russian, Alexander Alexandrovich Alekhine. Machgielis Euwe, whom Lasker recognized as a prodigy who had just won the Dutch championship while still at university, would take the crown from Alekhine in 1935 but lose a return match in 1937.

The title would not be contested for over a decade thereafter. Remembering the 1914-1918 chess hiatus, Lasker guessed that some new upheaval must be in store for the world. Whatever the trouble might be, he hoped Germany would be sensible enough to stay out of it this time.

In 1948, instead of a match there would be a championship tournament. Alekhine seemed unlikely to mellow with age; such a man would never surrender the title voluntarily. Despite Carey's discreet censorship, Lasker inferred that by 1948 Alekhine would either be deceased or too incapacitated to take up the cudgels, necessitating a tournament to find a new World Champion.

The tournament's victor would be one Mikhail Botvinnik—a name he had never heard of. Nor did he recognize any of the subsequent champions: Smyslov, Tal, Petrosian, Spassky, Fischer, Karpov, Kasparov, Sokolov, Seirawan, Enriquez, Steinfeldt, Ngo, Larvik, Tsuneta, Czyzewski, Adams, Akwai, Catalfio, Singh.

"All the games are given; the better ones are annotated," said Carey. "A lot of them are interesting, but you may get the most immediate benefit from a study of Lasker-Capablanca, Havana, 1921."

Lasker closed the book and leaned back, his face wreathed in blue smoke. "I see what you're up to. You're suggesting I study the match games—in advance, as it were—and find improvements to make at critical junctures when we actually play them. Sorry, but it won't work.

"I take it that this book is like your agents' documents. These are the games we will play—or will have played, or would have played—before your time-journey interfered with events? Or will have interfered?"

The convolutions of this time traveling, grammatical as well as causational, were dizzying; they reminded Lasker of those retrograde problems in chess magazines, which required the solver to reason backwards from a given position and deduce the moves that had led up to it.

He wished Albert were here. *That* one went simply and deftly to the heart of the knottiest questions (it was a pity he so disliked chess; he would have made a fine player).

But at least Carey was nodding as if Lasker had made sense, so he plunged on. "I'm sure that I can find places where I can improve my play. But that assumes that Capablanca each time will make the moves in this book right up to my planned point of divergence.

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"Chess masters, like good poker players, are sensitive to their opponents' moods. For instance, I've often felt a subtle tension in the man sitting across from me, rechecked my analysis, and found I was about to fall into a trap.

"If I sit at the board pretending to look for moves I've previously memorized, I'll be sending very odd signals to Capablanca. I question whether he may then be relied upon to produce the moves given here. Besides—assume he does. Match players often repeat a successful line of play, but if they get the worst of it they find an improvement or drop the variation altogether. After losing a game or two, Capablanca will just switch openings; I can throw away this book, and if we play true to form I'll still lose the match. You won't have this 'macro-change' you seek."

Carey smiled. "Very good, sir. Three hours ago you didn't even know time travel existed, and already you're a cogent theoretician. But I have another gift which should tip the balance your way."

He reached into the valise, pulled out five fat volumes with flexible silver-gray bindings. He stacked them beside the Shakespeare. "This is a comprehensive encyclopedia of the chess openings, with thousands of illustrative games," he said. "It's the 2030 edition, the last one ever published. An opening repertoire based on this will give you an enormous advantage over anyone in this era."

Lasker waved a hand in dismissal. "Opening theory! We need less, not more. Show me three recommended lines of play in a book, and I'll show you that two of them are unsound."

Carey shook his head. "I beg to differ. In the coming decades, far more grandmasters than exist today will subject the openings to minute scrutiny, and test their findings in hundreds of thousands of critical games. Toward the end of your century, computers will join in the task." He patted the valise. "This machine gave you only a small idea of the analytical strength of its bigger cousins.

"Before the year 2000, the best human players will be unable to hold their own with chess programs running on fast computers. One day the reigning World Champion will be defeated by a machine in a highly touted exhibition match.

"Later on, grandmasters' technique will have improved enough that they will pull even with the machines again. Not surpass them, just pull even, the way a slow kid playing tic-tac-toe with a smart one will learn how to force a cat's-game—a draw. By the time masters can hold their own again with computers, they'll also be unable to beat one another. They'll play draw after dull draw. Chess will be exhausted, played out."

Lasker nodded in comprehension. "Ah, the *Remis-Tod!* The concept has sometimes been argued in the chess press. Capablanca thinks it's imminent. I confess that I had hoped it would forever remain a mirage."

" '*Remis-Tod*'; 'Draw-Death'; yes. Even the infrequent wins that are scored due to human frailties will be unsatisfying. How would you like to win a pretty game, only to find that it was conceived years ago, and the antidote for the loser prescribed, in the bowels

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of a soulless machine? Fans will lose interest; tournament prize funds will dry up. The last world championship match will be played in 2039."

"Before the World War, in my book dealing with the question of free will," Lasker said, "I hypothesized beings I called *Macheïde*: creatures so well-adapted that they always make the right decision in any situation. They would seem to exercise free will, yet often would be so constrained by logic as to function almost as automata.

"Suppose two *Macheïde* sat down to play a chess match. Poof! Chess would be dead, for the best moves for both sides would be known." He spread his hands, said sadly, "I fear that in your day my *Macheïde* will have become reality." Then he brightened. "But surely, you could change the rules—for instance, add new pieces and expand the chessboard—and throw players back on their own mental resources."

"That'll be tried, but the daughter games will be short-lived," said Carey. "The praxis of classical chess evolved over the generations, like that of an art or science. Each age had its leading players and schools of thought. It took half a millenium for the game to be thoroughly played out. But in my time, as soon as a new variant comes into vogue, some clown runs it through a computer. Before long, the new game's questions are answered, and it's shelved."

For a long moment, the only sound in the room was the crackling of the fire, as Lasker tried to absorb the prospect of the death of one of the ruling passions of his life. Then Carey, seeming to sense his mood, said, "Enough, Doctor; chess is gloriously alive today, and there is plenty of history to be made—and remade. And your job is to beat Capa!"

This physicist, Lasker thought, little resembled most European professors; he was more like the lads leading the cheering at the one American college football game Lasker had attended. He had to smile at Carey's enthusiasm, but still he shook his head. "I'll take your word about the power of future opening theory. But even with its help I won't prevail, unless there is one more gift in your magic bag."

Carey scowled. "Was there something else we should have thought of?"

"Yes," Lasker said dryly, "a flask drawn from the Fountain of Youth.

"It's not enough to reach a won position; one must *win* it, move by move—often a lengthy process. When one is over fifty, the brain tires late in a long session. Blunders follow. You say I will soon grumble about the climate of Cuba; think what a sojourn there will mean to a man of my years, pitted day after day against an implacable, youthful foe.

"I'm well past my prime as a grandmaster. Last summer I offered to *give* the title to Capablanca, if only to silence the vicious critics who claimed I was dodging him. But popular demand and a handsome purse have decreed that a match be played.

"This evening, an old friend called on me: Doctor Ossip Bernstein. Do you know who he is?"

The games buff stared into space. Lasker felt gooseflesh again as he imagined the past evening's congenial dinner guest long dead, remembered only by

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a few hobbyists poring over game-scores and crosstables printed on yellowing pages. After a moment, Carey said, "Franco-Russian? Very talented amateur, but not quite in the first rank?"

"Fair enough. He's a financial lawyer residing in Paris, and is in Berlin just now. He asked if I have made any theoretical preparations for the match; I said no. He asked if I have taken time out to rest; I said no. He asked if I am at least packing a chessboard, to study on the voyage; again I said no.

"Grandmaster Bernstein looked at me wide-eyed and said, 'That's pure madness.' And he'd be right—except that I'm satisfied nothing will counter the age difference between myself and Capablanca. And just hours later, here you are, *deus ex machina*, offering me miraculous resources to make the very preparations I have already deemed to be useless. I'm sorry, my friend, but I'm still afraid you've made your journey for nothing."

"Past your prime?" Carey snapped. His voice was still quiet, but now there was heat in it. "I'll have you know that years from now, when you'll be no younger than you are now, a newspaper account of your first place finish in a great international tournament—*ahead of Capablanca*—will say 'The modern school came, saw, and succumbed.' But you'll never get a crack at regaining the title. Future generations will wonder why you surrendered it so meekly. It's unlike you; and frankly, I think it's beneath you."

Evidently regretting his sharpness, Carey stopped, reddened; in a moment he might even apologize, an embarrassing prospect. Lasker raised a silencing forefinger, smiled in reassurance, and turned away to stare into the fire.

Presently, eyes still on the flames, he said, "Perhaps you're right, young man. I may have been too much the defeatist. I agreed to play the match, did I not? People will buy tickets in Havana, and magazines and bulletins elsewhere. I owe it to them to at least make it interesting."

He looked at Carey, raised his eyebrows, clapped his hands in decision. "Why not? I *will* do my best—to give the public a real match, and you your 'macro-change.' "

Solemnly, the man from 2067 offered Lasker his hand; solemnly, Lasker shook it. Then a grin (of relief?) stole onto Carey's face. In a moment both men were laughing, like schoolboys sharing a secret.

Half an hour later, when Lasker showed him out, the American's grin was still firmly in place. He walked away jauntily, swinging his valise, his breath puffing white in the night air.

Lasker closed the door, yawned, wandered back to his fireside chair. He picked up a volume of the great openings compendium. On its limp cover was the poetic title *Closed Systems (I): 1 d4, d5; 2 c4, e6.* He riffled through its tissue-thin pages.

The variations were printed in compressed form, with tiny diagram symbols instead of letters for the pieces. Compact symbols—arrows, asterisks, squiggles—served as commentary. There was a key to the symbols in a dozen languages. *"White stands better"; "Weiss steht besser"; "Les blancs ont le meilleur jeu."* The encylopedists had

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eliminated the language barrier, allowing world distribution of a single edition. He wished he'd thought of it when he was publishing *Lasker's Chess Magazine*.

This book was what chess would become: a dry, dead inventory of every twist and turn from the starting position, knitting all the games ever played into one giant, crazily branching game-score.

In five minutes, two children taught the game the American had called tic-tac-toe could learn to block each other's *X*s and *O*s on a three-by-three grid. After five centures of shifting wood (and plastic?) across sixty-four squares, chess masters would reach a similar impasse.

But this was 1921, and masters were not yet so tediously accomplished. All roads might lead to the *Remis-Tod*, but this labyrinth of printed variations must include myriad false turnings that would entice anyone relying on today's chess dogma. Lasker thought of his own failure tonight to cope with this so-called Benko Gambit.

Capablanca was a great natural talent, but even by present-day standards his approach to the openings was lazy. He relied on his genius in middlegames and endings to see him through. By playing tricky and subtle variations of the future, Lasker could lure the Cuban into a deep pit at the outset of every game, quickly reaching a position so crushing that Capablanca's wizardry, and Lasker's age, could not become factors.

And after beating Capablanca, what then?

He closed his eyes, fingers caressing the book lying open on his knees. He could defend his title for years to come against all comers: Alekhine, Euwe, even this Botvinnik, whoever he was or would be. The great Lasker would wave his magic wand, conjuring up positions his rivals had no hope of fathoming, not over the board with their clocks running. Let them run home and work out the correct responses; the old fox would have another trick up his sleeve tomorrow, next week, next year.

His eyes flew open. He clapped a hand to his forehead, whispered fiercely, "I'm an idiot!"

For only now did he understand the full scope of Carey's experiment.

Lasker's successes would lead to detailed study of his published games. Others would absorb, and build on, the new ideas. The result would be a hothouse growth of theory. Opening systems would bloom—and, played out, fade—that otherwise would not have been seen for twenty, forty, sixty years.

It would immeasurably hasten the *Remis-Tod*.

What, besides the chess computer, was Carey taking back with him in his valise—the next hundred years' chess annals? How eager he must be to compare them with the distorted, truncated archives he expected to find in 2067. In what year had the last match for the world championship been played? 2000? 1980? 1960?

"I'm sorry, Mr. Carey," said Lasker to the empty room, "but under the circumstances, I cannot honor my promise."

And quickly, before he could change his mind, he fed the gray volumes, one by one, into the fire.

He hefted the *History of the World Chess Championship, 1843-2039*. It contained every world championship match that would ever be played. He

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longed to keep it, to read of the deeds of paladins yet unborn.

No. Once he had sampled the games of the future, his own play would be tainted, diverted forever from its natural paths. *These* games would never be played.

Almost reverently, he laid the red book on the flames.

Only the Schlegel-Tieck Shakespeare remained on the table. Lasker reshelved it; as he did so, Goethe's *Faust* caught his eye. "If he wanted something to read," he muttered, "*that* might have been more appropriate."

Perhaps that was unfair. Lasker had been World Champion long enough to know hero-worship when he saw it. The young man had wished him well, had really wanted to help him. Still, there could be no doubt that he had expected Lasker to be tempted to go on using the openings compendium, years after the match in Havana had been won.

And Lasker might have done just that if Carey, eager to defend the superiority of future chess theory, had not so artlessly mentioned the *Remis-Tod*.

It occurred to Lasker that he probably had done Carey a favor by destroying his gifts. For the World Champion sensed, as no hobbyist could, that the main premise of the American's experiment had been fallacious.

Chess might be "thinking pure as snow," but the game didn't exist in a vacuum; men of flesh and blood tried to earn a living from it. Some, like Lasker and Capablanca, were by and large successful; others were not. Old Steinitz was not the only master who had died in the poorhouse.

And sometimes the outcome of a single important game, making or breaking a career, made the difference.

Accelerating the growth of theory, the cut-and-thrust of innovation, refutation, rehabilitation, would have unpredictably altered individual masters' competitive results—changing their lives, the lives of their families, and all the lives they touched, in ever-widening circles.

Carey might have returned to an era he hardly recognized—if he had been retrieved at all.

Instead, he would find himself back in an all-too-familiar 2067 in which his project's funding would be cut off—and good riddance to it.

Capablanca would become World Champion. Lasker would somehow scrape along by his own wits. Grandmasters would go on winning and losing, tasting champagne and gall, until chess arrived at the *Remis-Tod*—slain by their honest toil and by the advent of electronic Ajeebs, Mephistos, Grandmasters-in-Your-Pocket.

As he reached into his jacket for a last cigar, Lasker's fingers touched a sheet of paper: Carey's note. With the air of an American tycoon igniting his cheroot with a double sawbuck, he used the note to light his cigar, then tossed the burning paper into the fire. The last tangible relic of the time traveler was gone.

One micro-change remained. For the rest of his life, whenever he played Black against the queen's pawn opening Emanuel Lasker would have to resist the temptation to play the Benko Gambit.

Dawn stained the windows and the embers in the hearth had burned low when the World Champion at last went off to bed. ■

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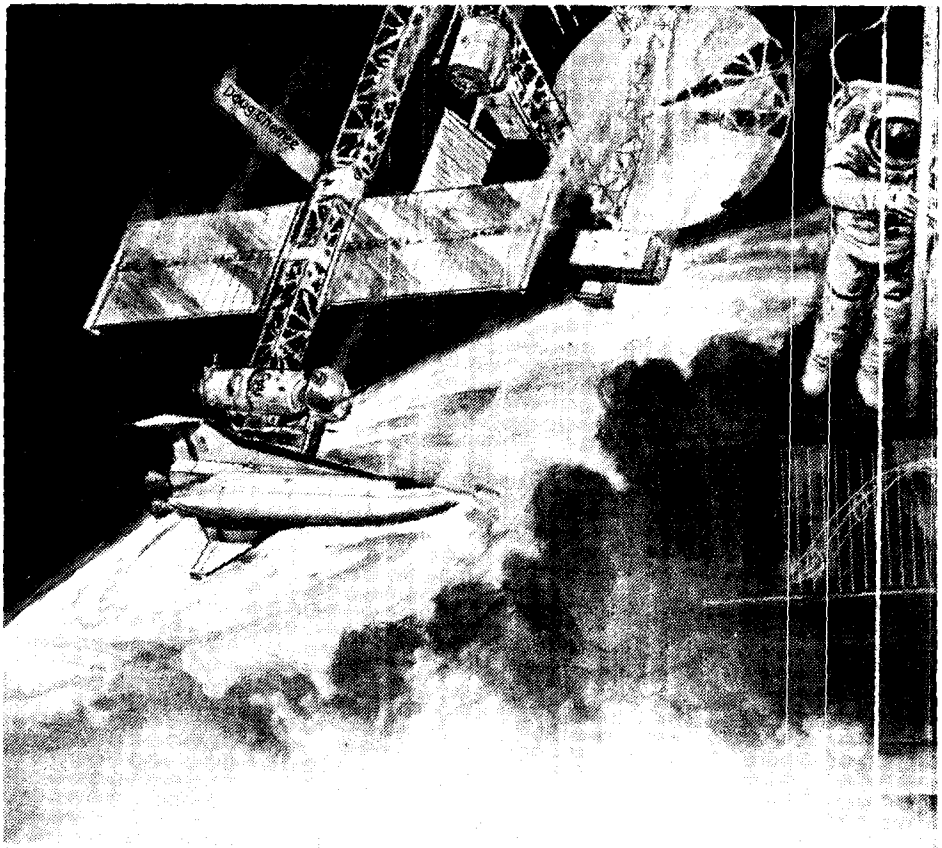

PULSEBEAT

J. B. Cather

People being people, completely rational approaches are not always the best way to get things done.

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The *Christa McAuliffe* sat proud on her launch site, a dozen vented vapors the only clouds in the crisp, perfect Florida morning. Gavin Murrow didn't have a radio glued to his ear like the thousands around him on the dried swamp of a beach so his binoculars brought him only a silent ballet of heat waves shimmering in the rising sun, wavering tails of vapor, and the incongruously hard white behemoth perched by the gantry, precariously balanced on the earth, waiting to fall upward to where she was comfortable. Earth orbit.

The sequence was an irksome ritual now. He'd been fifteen when Neil Armstrong made his one small step, and he was hooked. From Doraville, Georgia, it was easy to get to Cape Canaveral even if he had to hitch, and he made every launch until he went off to college. There was always plenty of traffic going the right way to take him to and from. And the people! The driver who picked him up might know a lot more than he did about the space program, or the other way around. Either way it was fun, guaranteed.

But it wasn't the same anymore. Now he felt the familiar sour taste building as he watched the launch.

Billows of white spewed from the engine nozzles, frantic and boiling, then were backlit with dull orange. The wave of sound rolled over him as the vehicle shuddered, straining for a second, and wrestled free. It fell away like a stone dropping upward, easy for the eye to follow at first, then faster, and very soon it was too far away to see, only its tail of flame burrowing into the blue.

Gav strained through the binoculars for the last pinpoint indication of light. It was gone in seconds. They could really pour the coal to it, now that they didn't have to worry about crushing fragile human bodies. Hoarse cheers washed over the beach, excited tributes to the new success.

He let his binoculars fall. The show was over.

The onlookers were buzzed, still pumped up by the vicarious thrill of another victory in the U. S. space program, another excuse to celebrate. Gav scanned the sandy flat. People gestured and yelled, animated, exuberant, pointing and opening new cans of beer. Like sea birds, the voices called in short, sharp meaningless yips.

He stuffed the binoculars in their case and turned his back on the circus. There was no point in blaming them, they didn't know. Any successful launch would be a victory. It seemed he was the only one who felt hollow when those big birds went up empty, exploring the new frontiers, leaving humanity behind.

And was that really the truth? Was he really angry over the principle? Or was he still only that same fifteen-year-old kid with an impossible dream, knowing this was as close as he would ever get to a ride in space?

The beginnings of the space station *Freedom* hung 300 miles above the Earth. This first phase was an erector set medley of beams, a cross of box frame trusses festooned with sail-like solar panels, precarious dishes and boxy modules. It was only two years since the crash program to build the station began and just over five months since robot welders fused the first girders. It wouldn't have started even then except

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for the alarming spread of AIDS and discovery that an antitoxin could be grown in space. Someday another cure might come along, or a better way to make this serum. But for now this was the only way to save the 200 million people worldwide who had the dread affliction, per capita three times as bad as Black Plague. And that was terrifying, for it would be ten times that in three years. Everyone faced the problem now, not just homosexuals and Haitians. Panic was poised, demanding a quick solution.

The Russians were growing the serum in their nearly operational Mir space station. But they made it very clear that the antidote would be available to the rest of the world *after* they met their own needs. Since they claimed that less than one tenth of one percent of their population was affected, this might seem a good risk. But the leaders of the Western world knew better than to hang their fates on that kind of hope.

So the orbiting space station, long in planning at NASA, was shoved to the forefront. Construction would have started even sooner but for the fanatical insistence by the Senate Space Committee that all flights be unmanned until "positive guarantees can be given for the absolute safety of the crew and passengers of any vehicle venturing out of the Earth's atmosphere."

"Positive guarantees."

"Absolute safety."

This *de facto* ban on humans in space had forced development of unmanned shuttles and robot machines small enough to fit in their bellies yet sophisticated enough to perform the thousands of construction tasks necessary to build the station.

It was an impressive effort. The "factories in a suitcase" had started arriving in orbit a year and a half ago. The first grew culture for the AIDS antitoxin using electrophoresis, where small currents separate proteins, a process so delicate that normal gravity will disrupt it. Other factories soon followed, for forming and extruding blocks of composite polymers into the tubular girders that would frame the station, or for making wire, or fasteners, or windows, or anything else needed.

Only the long central spine, the storage module and some of the solar panels were complete. The shape was recognizable, but clearly it would take years of work before it was done.

The shuttle *Christa McAuliffe* drifted up to the station, matching speed. There was no spin, so the docking maneuver might have almost been done without a computer. The *Christa* rolled gracefully and floated so her belly bumped gently against the storage module near the end of the unfinished spine. Smoothly and without hurry, recessed panels on the side of the orbiter opened and grappling arms unfolded, swinging outward to grip mating areas on the frame of the module. There was no one to notice that one of the arms snagged a wire that had worked free, crushing it between powerful, unfeeling metal fingers.

To the untrained eye, the heart of the Johnson Space Center in Houston hadn't changed in twenty years. Sure, there were new faces now, and the sophistication of the electronic equipment had probably doubled, but the monitors and

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control panels looked the same, there was the same amount of paper spread around and the room still pulsed with that same low, intense, controlled hum of voices exchanging information rapidly and efficiently through routine launches or frantic aborts. At the moment, they were monitoring the *Christa McAuliffe* through her post-offload checklist. Robot sleds were loading the small amount of unusable debris for return to Earth, but there was no return cargo as such. The only product being made up here was the AIDS serum, and it had another month to go in its year-long incubation cycle before it was ready. So watching the shuttle prepare for her trip home was just another routine exercise.

The voices chanted on, wearing detachment and professionalism like a badge.

"Final material loaded on board. Visual confirms sleds clear of cargo bay."

"Check. Closing cargo bay doors."

"Visual confirms cargo bay doors closed. Go ahead and take her home, Johnny."

"Acknowledge. Initiating automatic disengaging sequence. Now."

"Good job, people. Now just keep an eye on her and make sure she behaves herself." That was the voice of Leif Ericsson Raft, the mission commander on duty for this exercise.

Several of the technicians took off headphones and got up from their consoles. The remaining few kept reporting.

"Sequence initiated. Internal power up. Disconnect from station power."

"Confirmed."

"Retract gantry arms."

"Confirmed."

"Engines firing. And . . . away!"

"Wait one!" The casual onlooker would have sensed no concern in the voice, but the edge of tension was like a lightning flash to these veterans. "I'm getting a healthy wobble in station attitude. Did the *Christa* hit on the way out?"

Everyone scrambled for his stations.

"Negative. No trajectory on the shuttle. She never left!"

"Priority! Abort disengage sequence! All stations report! Give me some visuals, people. Shut down those engines. I want to know what's happening, and I want to know now!" The intensity in Leif Ericsson Raft's voice cut through the discipline of the room. Replies were snapped back.

"Shuttle motors off."

"Station attitude irregular. Can't get a meaningful reading."

"Station orbit decaying!"

"What?!" Surprise joined the worry in the mission commander's voice. "Shuttle team leader. Is the shuttle disengaged or not?"

There was a pause. "All indicators say she's detached and gantry arms are disengaged, but she's tracking right with the station. For some reason she never broke free."

"Prepare to fire retro rockets on the shuttle. Maybe we can undo this thing. But don't fire without my command. Get me visuals on the shuttle. Every angle. And orbital mechanics, calculate the trajectory of the station, and what boost we need to correct it."

"Sir!"

"What?"

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"I've got a visual. One of the gantry arms is still connected."

"Shuttle team!" the mission commander barked. "Reconfirm status of gantry arms!"

"Confirming, sir. This monitor says they're disengaged."

"Damn!" Startled, several people turned to look at Raft then snapped back to duty just as quickly. He rushed on. "People, we have to assume that the shuttle is connected to the station, and we can't disengage. Priority one is getting the station's orbit stabilized. Orbital mechanics! What do you have?"

"Still working. But her decline is forty seven point three feet per second accelerating to . . ."

"Belay that. Can I correct it with the shuttle motors?"

"Um . . . top of my head, it's swinging too fast. There's not enough thrust in the retro rockets. Any way to turn the shuttle around and use the main rockets?"

"Shuttle team, report."

"Negative sir. If we could do that, we could disconnect."

"Orbital mechanics. Any other suggestions?"

"Fire the shuttle's retro rockets. They're not big enough, but at least they're working in the right direction."

"Right. Fire the retro rockets." Leif Raft felt tired. This, he reflected, was why he was here. Most of the time things ran almost automatically, but when they went wrong, they went fast.

"Shuttle team confirming, sir. Retro rockets firing full."

"Very good. I guess that's all we can do for now, folks. I want two people visually monitoring the station at all times. Report immediately on any indications of damage or further malfunction. Orbital mechanics, remember you're priority one on defining the station's orbit and developing a fix. I want a control team in my office in five minutes consisting of orbital mechanics, STS and shuttle. The rest of you get some rest, but you're all on call twenty-four hours a day. John, you'd better call the Director. He'll want to be in on this."

With that he turned and walked out. The voices rose to a babble again.

Leif Ericsson Raft smiled at Lottie as he walked into the suite of offices.

She returned the smile warmly. "Good evening, Mr. Raft. He's expecting you. Go right in."

"Thanks." He went to the door, knocked quietly, and waited.

A voice from inside boomed out. "Come in. It's open."

Leif stepped through, smiling politely as he closed the door behind him. Robert Collier, the Flight Director for NASA, sat behind a desk with a few reports piled neatly in one corner, and some papers in his inbasket. He was a large florid man starting to bald who gave the impression of having it all under control. He was Leif's boss's boss and Leif didn't know quite how to treat him. They'd never spent any time together out of the office, and no one seemed to know much about him. But he had a rep for being hard as steel.

"Evening, Leif. Helluva day. Sit down."

"Thanks. Look, uh, I can tell you what I know, but it's a little early. . . ."

The big man held both hands up in

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front of him, palms out, as if shielding himself from the words, and waited for Leif to fade to a stop. "Before you start, there's one thing I want real clear. I'm in charge here. I need to know everything. *Everything!* And I need to know it when it happens, not the next day. Is that understood?"

"Uh, sure. Of course. I never intended anything else. It's just that we're still learning. A lot of the indicators conflict."

"That's fine." The way he said it, it didn't sound fine. "Just tell me everything you know right at the moment, and make sure everything you tell me is right. I won't be embarrassed. If new information comes in we can do this again this afternoon and this evening. As many times as it takes."

"Okay." Leif wanted to be supportive, but how was he going to do that? Some of this stuff was just coming in and was sure to be wrong. "Where would you like me to start?"

"How 'bout the beginning."

Leif tried to read him, but the man just sat there, impassive. Shrugging to himself, he began. "Somehow one arm didn't disengage from the space station, even though our sensors said it had. Since the shuttle was on automatic cycle, it fired its motors, trying to take off. That started the whole station spinning, and it precessed over and started to fall out of stable orbit. We can't stop it spinning or stabilize its orbit unless we can disconnect the shuttle and use it like a tugboat."

"And how long do we have?"

"Best guess? In about seven days it'll be down to a hundred miles and falling fast. At eighty miles it'll start to burn in the atmosphere. We'd never have a chance."

"And how are you doing on getting the *Christa McAuliffe* freed?"

Leif took his time before answering. "Frankly, we don't even know what's hung up. All our sensors tell us the shuttle isn't connected, but the camera shows the arm extended out there, holding on tight, plain as the sun."

Bob Collier was starting to simmer. "So what are you telling me? We don't know what we're doing? We don't have a chance?"

"I told you it was premature . . ."

The big man was up now, leaning over his desk, his face getting redder by the minute. "So the whole world is waiting for this serum, the President himself has been on the phone with me three times today. And all I can tell him is we're going to fry the only place that can make it, set the program back a year, kill hundreds of thousands, hell, millions of people, all because of a stupid screwup by *my* people! And we can't do anything about it! Is that what you're telling me?"

"Well, no, not exactly . . ."

"You're damned right, no. Hell, no. Goddammit, no. Whatever's the clearest way you can say it. Capital N, capital O. *That will not be!*"

Leif just sat there, wondering how he was supposed to answer that. He wanted to save the mission more than anyone, but what could he say? "Bulldog" Collier was rabid. And impatient. Leif knew not to show fear to a bully. Eventually he offered, "We're trying everything we can."

"That's not good enough."

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"It has to be. I mean literally everything. We're covering all the bases."

"Like what?"

"We've got the people who designed those arms in here, and designed the sensors, and they're brainstorming . . ."

"And you're getting nowhere, right?"

"So far we haven't . . ."

"I thought so." He stood back up and walked around the desk to confront Leif. "What else?"

"We've rushed the completion of the second unmanned shuttle, but it'll be thirty days before . . ."

"Great!" he snarled. He was leaning close now, almost in Leif's face. "What are you doing that has a chance of working?"

"There's one other approach right now, but it's a long shot."

"It's got to be better than what I've heard so far. What is it?"

"We could send up a manned shuttle, if we could . . ."

"Are you crazy? Those things have been hibernating for too many years. Who'd fly one?" Collier flopped back into his chair.

"That's one of the problems, of course. But the last group of twelve astronauts was a pretty good class, and we're trying to locate them now. This is a one-shot, one-man mission. If any one of them is still in shape we've got their suits and gear ready."

"And you can drag one of those relics out of mothballs and have it flight-ready in seven days?"

"Two."

"What?"

"It'd have to be two days, to give him time to get up there, rendezvous, and correct the station's course."

"That's crazy. Rushing one of those things off the ground got us in trouble back in '86." He stopped and rubbed his temples. Leif hoped he was in pain. "But once it's up there you're sure it can do the job?"

"If we can load enough fuel into it. It's not really built to be a tug." Collier turned and glared again. Leif returned his look levelly, then in a low voice asked, "You have any better ideas?"

"You're supposed to come up with the ideas, not me!"

"Okay, we have. You've heard 'em. Which one do you want to go with?" Leif wondered if he was pushing his luck by giving this guy an open door.

Collier thought for a moment, then scowled. He shook his head grudgingly. "All right. The manned shuttle sounds like the best shot, even if it's a long one." He wagged his beefy finger. "But you go over the plan with a fine-tooth comb. We're not having another national disaster under my administration."

"Yes, sir."

"And don't slack off on any of the other options!"

"Yes, sir."

"And I want reports on my desk tomorrow on the *Atlantis*, *Columbia* and *Discovery*, and each of those twelve astronauts."

"Yes, sir. Is that all?"

"No, that's not all. You got me into this mess, and you'd damned well better get me out of it!"

"Yes, sir." Leif backed out the door.

There was a small crew in the command room of the Johnson Space Center, but it lacked the usual detached

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professionalism. This may have been because outsiders were here, designers and engineers flown in specially to work this problem. But even the regulars were jumpy, rushing through calculations, guessing at input data, pressing each other for answers, wrangling over philosophies, and generally getting on each other's nerves.

When the next shift came in at three in the morning they grumbled about lack of progress. Leif Raft called in about quarter after. John Dougherty took the call. "Good morning, chief. What are you doing awake?"

"Thinking. How's it going?"

"Not good, I'm afraid." John hated making it sound that negative, but the chief liked to deal with things straight up. "The orbit's in an accelerating decline."

"What about our experts?" The chief was angry. He never let it show, but you could tell sometimes. "Any ideas on why we're getting false readings on that arm?"

"The electrical guys are sure it's a defective sensor, and the mechanicals swear it's a bad signal path somehow."

"Doesn't sound like we're getting anywhere."

" 'Fraid you're right, chief."

"Well, thanks, John. I can always count on you to level with me. And call the minute something breaks, okay?"

"Sure thing."

Post-midnight oil also blazed in the offices of Spearhead-Bowington. Fred Hanratty was standing at one end of a conference table, sleeves rolled up, bleary-eyed, overdue for a shave, and clutching a Styrofoam coffee cup in a gesturing hand. He ignored the splatter that slopped onto the end of a long roll of white paper, a critical path diagram used to schedule building the second unmanned orbiter. The table was littered with schedules and charts and more were tacked all over the walls, some covering the ones put up earlier.

Fred was tired and running out of time, but he reminded himself that here he spoke for NASA, one of the premiere organizations in the world, and redoubled his strained efforts to remain professional. "Look, I don't have that much time, I'll be back in Florida at eight o'clock, four hours from now, and I have to give Leif the date this orbiter will be ready to go. What am I going to tell him?"

They all started at once, voices indistinguishable but tones emotional: angry, anxious, afraid. He held up a hand, and took a swig of coffee. "Hold it, old it. One at a time!"

In the brief pause Mickey Blauvelt jumped in. "Come on Fred. You know it's not that simple. It took us months to develop that schedule. We can't just redo it overnight."

"I know how long it took, Mickey, and I appreciate the work that went into it. But you've got all this to work with, that's got to give you a head start. And I don't have the time to do this from scratch. So help me out, will you? What's the best you can do in the next couple of hours?"

"Couple of hours?!" The screaming started all over again.

The mercury vapor lamps lit the runway with an eerie purple glow, bright as daylight under an alien sun. All that

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light seemed wasted on just the man in the suit and the three men in coveralls working inside the huge hangar. One forklift moved a final pallet out of the way exposing the bulbous snout of the space shuttle *Atlantis*. The man in the suit said "All right!" to himself, half under his breath, and went over to pat it like a horse.

"How long before we can get out in the open?"

The one on foot stopped deliberately and turned before he answered, as if it were an affront to be interrupted from directing the two forklifts. "Twenty minutes, half an hour."

"Okay. You guys keep going. I've got to get some other people out here." He hurried off.

The foreman grimaced at his retreating back. "Sure thing."

The blue-eyed, blond-haired man in captain's bars couldn't have been much over twenty-five, but he had an office in the Pentagon. It wasn't a big office, in fact it wouldn't have been a very big closet, and his uniform looked fresh out of the box.

He knew he was at the bottom of a very tall totem pole, and he was willing to do what it took to keep climbing. But, for heaven's sake, why did they need a Captain for a job like this? A chimpanzee with a modem would make more sense. Well, he muttered, the right way, the wrong way, and the Air Force way. He dialed the next number on his list and waited for the connection.

"Yes, ma'am. I do know what time it is, and I'm very sorry. I wouldn't be calling except for something extremely important. Is Colonel Moreno there?"

He listened politely.

"Yes. I know he's a famous astronaut. I'm very sorry to be bothering you but it's awfully important that I locate him. Is he there?"

He listened again.

"Certainly I'll wait."

He waited.

The receptionist looked very efficient. Better yet, she was. That's one reason Phylis had the job she did: receptionist and administrative assistant to U.S. Senator Jordan, the pride of North Dakota. She knew enough about how things worked in Washington to handle some callers, redirect others to places that would make them happy, and save the special few for the Senator.

This one would go through. "Well, of course. I'll see if the Senator is free. Would you hold on for a minute, please?"

She rose and went the five steps back to the office door, tapping on it lightly. She didn't wait for a response, knowing the Senator was alone in there. Alone, that is, except for all fifteen pounds of Senate Bill #937.

Phylis went in. Senator Jordan looked frazzled. Her suit jacket was draped over the back of the chair, and the neat bun she'd worn her hair in that morning was coming down. If not for the red and blue pencils thrust through it there would have been nothing left. But her sudden smile was bright and honest as ever.

"Oh, hi, Phylis. Did you come to rescue me? Was the dragon's fire seeping out under the door?"

"Nothing that dramatic. I'm probably just getting you to trade one drudg-

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ery for another, but there's a call on line three I think you should take."

The Senator brightened. "Anything but this. Who is it?"

"NASA. A General Schwarz."

"Oh, good, I haven't talked to Tom in ages. Line three?"

"Uh-huh."

Phylis waited in case she was needed. The Senator was all smiles when she picked up the phone. "Tom? How are you? It's good to hear from you. How long has it been?"

Her face sobered then turned completely grave. She listened in silence for half a minute, then spoke again, her voice shaky.

"Oh, Tom, that's terrible. I can hardly believe it . . . Well, is there anything I can do? . . . Oh, well of course. Yes, I'll be on the next NASA charter flight . . . Certainly. Goodbye."

Phylis couldn't contain her curiosity. She was speaking before the phone was in its cradle. "What's the matter? Oh, I hope it's not a death in the family?"

The Senator looked up, her mind still elsewhere. "What? Oh, no, Phylis. Nothing like that. It's just . . . unh, I really can't talk about it. Would you cancel all my appointments? And clear my schedule for, I don't know, say a week?"

"Certainly." Phylis waited.

"I'd better go right home and pack. Call me there and tell me when the next NASA commuter leaves Dulles, okay?"

She smiled brightly at Phylis, but her mind was obviously elsewhere. She was out the door and gone in a flash.

Captain Andrew Jackson Direr, USN (Ret.) was the biggest surprise of the lot, thought Medical Staff Sergeant Gary Bixby. How did he expect to pass this physical? Five years ago when Direr retired at the disbanding of the astronaut corps he had been taut and trim, an officer held up to the new recruits as a model. In just five years he looked his age. All the returning astronauts were in worse condition than when they had been under NASA regimen, but a change like this was startling. And the way the buttons on the uniform were straining just made it worse.

Gary crossed to the window and pulled the shade down. "That afternoon sun is a killer when it angles straight in like that."

He turned around and rubbed his hands, wondering if he looked like a doctor in a TV commercial. "Now then, Captain Direr . . ."

That paunchy belly wobbled as the man interrupted. The chin followed. "It's Mr. Direr now, and I'd really rather you call me Andy."

"Andy it is. Now, why don't you get undressed and step to the examination table. Those clothes must be very uncomfortable." *Damn! Didn't mean to say that!*

"Right. They don't fit the same after five years in the box."

"Well, I didn't mean anything . . ."

"Quite all right. I'm not the man I once was. Can I hang these here?"

Phil realized he had let his gaffe throw him off, and tried to regain his composure. "There's a hook on the back of the door. And some hangers."

"Down to the shorts?"

"They have to go, too."

"I was afraid of that."

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The examination was routine. At least routine for a middle aged executive who didn't get enough exercise.

"I'm not sure how to tell you this. We usually withhold judgment on a physical until it's been reviewed by the staff, but I'm afraid you're in no condition to go up in a shuttle. I can tell that without further consultation." He was talking fast now, embarrassed. Captain Direr was looking at him blandly, waiting his turn to speak. Phil didn't want to hear what the man had to say after he'd hurt his feelings like that. He rushed on. "I'm sorry if we wasted your time, asking you to come here."

The middle-aged man watched him with bird-bright eyes for a minute, then smiled. "You're not telling me anything I don't already know. Still the boys at NASA said they needed some help fixing a problem, and I wouldn't have been able to live with myself if I didn't come down and volunteer. Least I could do." He was getting up and heading for the dressing closet now.

"Wait!" Phil wasn't sure what he was going to say. "I didn't mean you were in bad shape or anything, you're perfectly healthy. It's just that for an astronaut . . ."

The Captain turned and smiled at him. "At ease, son. You're just doin' your job, same as me. I guess we've both done our part now, and can move on in clear conscience."

When Andy came out he had his uniform pants on, but only an undershirt above the waist. He was carrying his coat and shirt, and somehow it was easier to think of him as a civilian now than when he was naked. He took a quick measure of Phil, and shook his head. "Still feelin' uncertain? Don't. But tell me, how's it goin'? You found any yet that make the grade?"

"Well, it's a little early to tell." Phil paused discreetly.

"That's all right." Andy smiled. "None of us really expected to be asked to come back and do this again. Well, maybe only one. If anyone else is in shape, it's just luck."

"Well, actually, we have one good man already. But we're still waiting to examine a few."

The round face broke into a shrewd grin. "Gav Murrow?"

Phil was surprised. "No he hasn't been through yet. It's Benny Li."

"Hmmm." The older man nodded his head approvingly. "That's good. Means you'll have at least two."

The Sandpiper was as noisy at four in the afternoon as at ten o'clock at night when the pickup crowd came in. Gav was in his spot in the corner near the TV, rewarding himself for a brisk ten-mile run on the beach. His glass was only half empty when a voice behind him said crisply, "Major Murrow?"

Gav twisted to appraise the Marine Lieutenant, shiny-buttoned and crisp-creased, and his festive glow started to slip. "Aren't you people tired of dogging me? I haven't demonstrated against you in two years!"

The Marine looked uncertain and backed away a step. Gav instinctively stood to confront him.

"I don't know anything about that, sir." The kid looked nervous. "You're supposed to come to the Cape, sir. It's urgent."

"What for?"

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"It's classified."

"Then I'm not going." Gav sat back on his stool and picked up his glass, returning his attention to the TV.

The Marine came up beside him. "They told me you'd say that, sir. Here's a letter from General Schwarz."

Gav studied the profferred envelope suspiciously while he enjoyed one more swallow. He tried to look his most irritated as he took it, mostly to hide his curiosity.

"There's a limo waiting right outside, sir." The jarhead never knew when to quit. "If you could read it in the car it would save time."

"I'm not setting foot off this stool until I . . ." But by then he'd scanned the first paragraph. His face felt suddenly cold, and he wondered if the blood had drained from it.

He grabbed his sweat jacket and slid off the stool. "Let's go, marine. You're holding me up!"

Even though he had a lot more information Leif Ericsson Raft knew less now than he had at the beginning. He hated going in to see the Director again, and responded to Lottie's greeting with a distracted grunt. Then Collier's door was looking him in the face and he had no other choice. He knocked. The same uncheerful tone invited him in.

Bob Collier hadn't changed a bit except he wasn't quite as red as when Leif saw him last. It didn't take long to correct that. He started out belligerently and his color grew. "I thought you were going to keep me informed!"

"I am. That's why I'm here."

"This is only the third time in thirty-six hours that you've been here, and I've practically had to drag you down even then. Didn't you think there was anything I needed to know about?"

Might as well get it over with. "Not very much. I'm afraid we're no closer to understanding why the shuttle won't disengage. And the station's still falling, still in accelerating decline."

The big man ran his hand through his thinning hair. "That wasn't what I wanted to hear. What about this plan to separate the serum factory and keep it in orbit?"

"Crapped out." Leif was tired of recounting his failures. "Once we separate it from the station the buggies wouldn't live three days. We'd never get a new shuttle up in time. And even then we couldn't bring the serum into gravity without killing it at this point. And we couldn't keep it alive in the shuttle."

"Wonderful!" Collier used sarcasm like a club. "So what's left? Have we run out of time on sending up a manned shuttle?"

"No." *Didn't he ever lighten up?* "*Atlantis* is being moved to the Cape right now. It's double fast track all the way, but she should be ready to lift off tomorrow morning some time."

"Really!" Collier actually sounded pleased. "I figured that'd snafu, too. Why didn't you tell me that first?"

"It's not all good news. We practically had to gut her to do it. With the engine mods and the revamp to fit the spare fuel tank, she'll never be good for a normal mission again. We took out everything we could, seats, spare suits, non-essential instrumentation, some of the backups."

Collier waved it off. "They're mu-

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seum pieces anyway. You're doing the taxpayers a favor. Who's going to pilot it?''

''I don't know. Three of the astronauts are still in good shape and remember their training. The rest just aren't close.''

''And who are the lucky three?''

''There's Senator Jordan, and Benny Li, he's President of Jefferson University. And Gavin Murrow. He's retired.''

''Retired!'' The director snorted. ''What's that mean? What's he do?''

''Nothing, really. After the manned program was dismantled, you know how vocal he was. That soured a lot of folks on him. None of the corporations or universities would touch him, and the service pressured him into retiring.''

''Oh yeah. Him. He was a real pain for a while.'' The Director shook his head angrily at some memory. ''So what does he do now, anyway?''

''Nothing much. He still talks to anybody who'll listen, but mostly he just hangs around dreaming of being an astronaut again.''

''Not if I have anything to say about it.'' He thought for a bit. ''This isn't working the problem, Leif. Who's the best pilot?''

''Jordan. But you don't need a crackerjack pilot. It's pretty much flown from down here.''

The face went florid again. ''Don't lecture me on the shuttle. If Jordan's the best pilot, she's most likely to get the job done right. Jordan it is.''

Bob Collier walked around his desk and sat back down to think. Leif didn't say a word, afraid he'd tell this pompous limpbrain what he really thought.

The silence lengthened. All the frustrations ate at Leif, the pressures of the last day and a half magnifying themselves. He wondered why he put up with it, resenting the interruptions Collier generated, about the only thing he seemed capable of.

But the more he fumed, the more Collier relaxed. Soon he was smiling broadly. ''You know, this might work out real well. She'd be a hero, and bound to go places in politics. And she'd owe us some big favors for putting her there. I like that. I like that a lot!''

He looked across at Leif. ''As of right now, that's our prime scenario for solving this problem. You concentrate all your resources on making it work.''

Leif exploded. ''Goddammit, Bob, don't you think I'm on top of this? Why don't I leave, just get out of your way, and let you do it all?''

Collier half rose and stabbed a finger at him. ''Hold it, Leif, hold it right there. I give direction, that's why they call me a director. You've got no reason to get ugly. You have some problem with my decision?''

''Yes. Yes I do!'' He was up now, pacing back and forth as he talked. ''You don't know everything.''

''Then tell me, goddammit! That's what you're here for!'' Collier's bulldog jaw was thrust out now, and he looked ready to pop up over his desk.

Leif stopped striding. ''Fuel, Bob. There's not enough fuel. We've crammed in 80,000 pounds of extra fuel in a 65,000 pound payload vehicle by converting the cargo bay to a fuel tank. That should be enough but it's going to be awfully close. If there's trouble she may not have enough to get back down.''

The Director studied him shrewdly.

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"What are you saying? That we can't save the station?"

"If we get up there we'll save the station. Even if we only slow down its fall we've bought enough time to get an unmanned shuttle up there. We just don't know how much fuel it's going to take to get the station back in stable orbit. We're playing craps with a man's life."

Collier slumped for a minute, staring down at his desk. Then he rose and came around to press a fatherly arm on Leif. "You know, I understand. It's an ungodly tough decision, and I'm really impressed that you've been able to deal with it so well."

He glanced at Leif and went on. "Think about what we're dealing with here. This AIDS thing is a horror. There's more lives in the balance than we can meaningfully comprehend. And I know these astronauts. They're brave and proud, every one of them. What do you think they'd say if you asked them to go up under these conditions?"

Leif waited.

"Come on, just imagine any one of them. What would he say?"

Leif was feeling sick. By his silence he was agreeing to murder. "Don't you think I've thought about that?"

"Now, get yourself under control. I understand what's troubling you, Leif, and I respect you for it. That compassion is what makes you a real leader.

"And I'm going to make it easy for you. You know this is the only answer." He sighed dramatically. "I am ordering you to prepare the manned shuttle for launch, knowing the possibility that it may not return." The Director looked grave.

Leif said, "You don't have to make that decision."

"I know." Collier looked up into his eyes. "But I need to do this, for my own reasons. It's on my head now. All you have to do is implement it. Is that okay?"

Leif shook his head. "I know what you're saying, of course. And don't think I don't see its merits. Cold logic says it's the only answer. But when I think about telling them, when I see their faces . . . I just have a real hard time treating good people like this."

"But you see my point?"

"I can understand your decision, and I can accept your direction. I'm just not comfortable with . . ."

"Good. Good." The heavy arm was around his shoulders again, and he felt himself being walked to the door. "Now I know you've got a thousand things to do, so I won't keep you."

He stopped at the door and shook Leif's hand. "Thanks, Leif. You're doing a hell of a job."

"Yeah."

He turned to go. When he was halfway out the door, Collier's voice stopped him. "Oh, Leif, just a few more little things. Part of the order."

"What?"

"Murrow is going to pilot the shuttle. And since there's no on board gauge for the new tank, don't mention the fuel problem. It would only hurt his concentration." He smiled grimly. "Orders."

Leif watched the door swing gently closed in his face.

Gav felt pretty good.

This whirlwind approach to preparing

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for a launch was decidedly to his liking. By rights he should be slowing down the show. If anything went wrong, *his* ass was in the cradle. Instead he was exhilarated. He'd always believed all those procedures were merely a sop: this equipment was so complex that no one really understood it completely. All this checking and backing up of critical equipment was great as far as it went, but while they were feeling good about the problems they averted they probably missed a dozen others that would fry his eggs. In the end they were trusting luck more than they knew.

And that was fine with Gav. Luck had always treated him pretty well. He was here, wasn't he?

The door to the conference room opened and intense young men began to come in. After a hectic twenty-four hours, Gav had enjoyed the solitude. The quiet had given him a chance to reflect. He was sorry it was interrupted.

The first three had all the earmarks of NASA: clean-cut, bright, a little too eager. He didn't recognize them, must be new hires since his days. Then Leif Raft came in, busy as ever, reading while he walked, and carrying on a conversation in shorthand with some technical type.

Gav felt a genuine joy. This was a man he had always respected, and it felt good to be working with him again. He was up and smiling, sticking out his hand. "Leif, you ol' rattlesnake, how you been?"

There was a funny look in the mission commander's eyes and Gav wondered if he wasn't used to such casual greetings any more. *If he was getting that stuffy it would do him good to loosen up.* After a second of surprise or confusion or something, Leif opened up. His smile looked genuine.

"Gav! Good to see you!" Leif appeared tired. "You look terrific!"

Leif didn't say things just to be polite. Gav looked down at himself and grinned. "Yeah. I've been trying to keep in shape. Haven't had much else to do."

"I heard. You doing okay?"

If you knew Leif, you knew that was a question that asked much more than it seemed. Gav answered truthfully. "Fabulous. Now that I'm here."

"Good." Raft looked to see that the others were already sitting, and pulled out a chair. "Well, we might as well get to it. You know everybody?"

"Yeah." Gav didn't, but it wasn't worth making a point of. He found a chair.

"All right, Gav. This is your final briefing." He looked up from his notes. "And in this case, your only one. Like a lot of other things on this mission, we're cutting corners to save time. But I want you to know that a lot of people are working very hard to make this just as safe as a normal mission."

"Hey, don't make a fuss." He tried to sound reassuring. "I feel good about this. I know you won't sell me short."

Raft looked like he was going to say something but he went back to his notes.

"Uh, thanks. Now, lift-off is tomorrow, oh-seven-three-oh. You'll rendezvous with the space station after thirty-two hours. Then you'll have about two days to get the station back in stable orbit. We think we can do it in six hours once you're hooked up right, so you should have plenty of time."

He looked up again, directly into

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Gav's eyes. "And watch your fuel. We've converted the cargo bay to a fuel storage. It was hokey, like everything else we've rigged up: there's no gauge and you've got to throw a switch when the main fuel is gone, but it'll work. So you have eighty thousand pounds extra fuel, but this trajectory isn't optimized and we don't know how much you'll use wrestling with the station. Assume you'll need every drop."

"You guys do the calculations. I just drive the truck. When I get down close to the big red E on your simulated analog CRT readout just give a holler." He laughed at his own joke, but he seemed to be the only one enjoying it. Well, people didn't always think he was funny. "Just trying for a chuckle there, fellas. Never doubted for a minute that you had it completely under control."

There was an awkward silence. His jokes weren't *that* bad. The silence hung until Leif, sounding strained again, said, "Well then, let's move on. We've got a lot to cover. I'll be flying to Houston in four hours, so we'd better get cracking. Your launch controller at Canaveral will be . . ."

They used those four hours and wished they had more. When the others had to run for the plane, Gav headed for a final suit fitting, happier than he'd been in five years.

Takeoff was flawless. His first trip in a shuttle, and he hadn't had to wade through the months of training or a lot of fuss and publicity. This one was over before he knew it and he was finally here. Briefings on last minute changes and surprises uncovered by the checkouts had kept him up all night but he didn't care. He was too hyper to sleep anyway.

After the launch, through the enforced idleness of accelerating to orbit, he let his mind wander. Daydreaming in the *Atlantis* when she was under way had to be a lot like sleeping in a bus while it rolled through Kansas but in the bus you'd have more room to stretch. Gav wanted to keep floating in his thoughts, but that damned buzzer was going off in his headphones. Then the voice started.

"*Atlantis*, this is mission control. Do you copy?"

Gav brought himself back.

"Repeat, *Atlantis*, this is mission control. Rise and shine, cupcake."

"Yeah, Houston, this is *Atlantis*. For the record, I never set my alarm to music at home because I hate cheerful disc jockeys."

"Thank you, *Atlantis*, we accept the compliment. Wedge toothpicks under those lids and glance ahead and to port. See anything?"

Gav leaned forward and looked. It wasn't so much black out there as it was colorless, like a well-lighted room where the walls are too far away to see. "I'm working at it, Houston. Where should I be looking?"

"About eleven o'clock, and a hair below your nose. You should be close enough for a visual on the space station."

"Wow! Am I ever!" He was alert now. "I can't quite make out the shape, but there's something big out there with huge white solar panels."

"Good. We'll bring you in and you can take over for the final docking. Ready for course correction. Verify

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delta vee two hundred seventeen feet per second. Fire in ten seconds."

"Ready." Gav sat deeper into his padded seat. After launch these small boosts were nothing, but he never assumed anything was going to be easy.

They nudged the *Atlantis* up to the space station one small boost at a time. Gav did a lot of waiting between commands, and the show just got better and better. This was why he wanted to come up here. The simulators were supposed to prepare you for space flight, but it was like the difference between board games and videos. They just didn't have the *life!*

The station was coming up now, the main structure a grey-black skeleton, made of tubes of some graphite composite. The members crisscrossed into trusses, indistinguishable from their own stark black shadows thrown by the unshielded sun. Like huge white sails, solar panels perched along the spine, turning to keep their best face to the sun as the station rotated. The *Christa McAuliffe* was perched uneasily on the end nearest the lab module, belly in, like a mosquito landed there and not yet done drawing blood. She was unwieldly compared to the delicate grace of the structure and Gav wished she would be thrown from the slowly turning spine to return the visual balance.

Houston maneuvered the *Atlantis* in until the station was turning lazily and he was floating off the end of the latticework frame a hundred meters high and nose-in. Then they thrust him sideways, sliding in a circle. It was disorienting at first until he started concentrating on the station as he gradually came into synch with it. A few more light touches by the rockets and finally the station was unmoving below him and the Earth was wobbling crazily underneath.

Gav had been ignoring the chatter, mostly ground talk, caught up as he was in the spectacle. Then they started talking to him again. "Houston calling *Atlantis*. Come in big bird. Do you read me?"

"Loud and clear, Houston. No need to shout."

"Wasn't sure you were still with us."

"You should be sitting where I am. The view is spectacular."

"Bet it is. Can you tear yourself away long enough to do a little jockey work?"

"Yes sir, that's what I'm here for. You guys get the easy part, I do the rest." He grinned, hoping they were watching.

"Put your money where your mouth is, Tom Corbett. Have you located the point where you're supposed to touch down?"

"Roger. You have me set up pretty well. I'm right above it. Do I have the con?"

"This is Houston confirming transfer of *Atlantis* to local control. All yours, Gav."

"This is *Atlantis*, now under self control. I'm easing her down."

It took several minutes of maneuvering. He'd been away from this too long and the controls felt stiff, the shuttle unwieldy. But he forced himself to take it slow. Houston encouraged him. "You look good, *Atlantis*. Coming down soft as a feather."

There was a soft *thump* and he cut

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the jets. "This is *Atlantis*. How did I do, Houston?"

"Right on target."

"Good. I'm going to do some manual labor. Control back to Houston."

"Houston acknowledging. We've got control."

He patted his helmet just to be sure it was still perched on its stand, and disconnected his umbilical. Unfastening the belts he clambered up out of the chair and turned to his left. This was the first time he'd really been free in zero *g* and he wanted to do cartwheels like the mid-sixties TV shots had shown.

But he didn't.

Attached to the floor, in the place where the other chairs should be, huge frameworks were clamped in place by hastily welded brackets. Unscrewing the cap on the tube welded to his chair, he slid out the specially made wrench and set to undoing the structures.

Eighteen bolts later he had freed the three large frames and moved them over by the escape hatch. Zero *g*, or at least low *g*, had its advantages. He sat back down in the padded chair and activated the radio. "Houston, this is *Atlantis*. I'm ready to go out and play now."

"Roger, *Atlantis*. We'll keep an eye on you."

He found his helmet and lowered it over his head, clipping it down to the bulky space suit. After checking his life support and communications systems he flipped back a red protective cover on the shuttle's control panel and pressed the button underneath. The hatch opened and air escaped with a sigh. He climbed over the frames, backing through the port. Unhooking one end of the safety line from his suit he snapped it into the quick disconnect near the port. Feeling like a kid who hangs back a few seconds before coming downstairs on Christmas morning he counted to ten then pushed himself out.

It was better than he expected.

It wasn't even the colors, or the majesty of the structure, stately and solemn. The vastness of space was incomprehensible, even from here, and the Earth, milky blue and white, didn't look real. Any one of those things would have been impressive, but somehow the whole was much, much more than the sum of its parts. Or maybe it was just knowing he was finally here. It was exhilarating.

He allowed himself a brief draught of ecstasy, then got down to business. He'd treat himself to a space drift later, but now time was critical. Pulling himself in hand-over-hand, he flipped up a recessed panel on the side of *Atlantis* and confirmed that the freshly welded lugs and their pin connectors were in place.

Headfirst into the hatch, he backed out again dragging the first of the frames with him. It fit neatly against the side of the craft, and matched perfectly with the lugs. The pins were through in seconds.

The *Atlantis* was perched in the middle of the main spine of the station as close to the center of gravity as they could get. The frame that he had just attached dropped "down" along one side of the spine. He fitted the second on the other side, and the third bridged across the bottom. A simple threaded joint allowed him to cinch the assembly up tight before bolting it firmly in place. The shuttle was anchored.

Back inside he let Houston know he

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was completed, and got a cheer. He relaxed as they did the heavy work of correcting the decaying orbit of the station. He sat through two hours of full firing before the shuttle engines sputtered out. Throwing the switch to start the flow of auxiliary fuel from the converted cargo bay was a brief reprieve, then he was back in his chair, resigned to another deadening four hours of throbbing rocket motor.

He let his mind range even farther than he'd already come, enjoying everything he could see and envying the men who would someday go farther and see more. The radio pulled him back.

"*Atlantis*, this is Houston. Do you copy?"

"I hear you, Houston." The shuttle's engines were silent. "It's awful quiet. Are we there yet, Daddy?"

"No time for jokes, Gav." The voice sounded strained. "This is Leif Ericsson Raft. I've ordered a halt to firing the engines."

Gav sat up straight. "A halt?" He sounded halfwitted, even to himself. "You mean we did it?"

"No!" The voice snapped. "The station is still falling."

Gav waited. The man was telling him something important here, but he couldn't seem to spit it out. "Go ahead, Leif. You have my full attention. What is the situation?"

There was silence for longer than he liked. When Raft spoke again, he had a hard time keeping his voice steady. "Gav, look. I ordered them to stop because right now you've got enough fuel to get down. If we fire any longer, you won't make it."

This was a little hard to absorb. His mind worked with the concept while his body knotted up, a separate primordial creature.

"Am I coming through, Gav? Do you understand me?"

"Acknowledge." Gav managed.

"Good. Get out, unhitch yourself, and come on home. You're a hero, Gav. We'll have a parade waiting."

Again Gav didn't answer. Thoughts were whipping through his mind too fast to grasp. He was trying to get a grip on all this.

The radio growled again. "Gav, do you copy? Are you on your way?"

"Wait a minute." His voice sounded hoarse in his phones. He cleared his throat and determined to sound stronger. "There's a few things I need to know."

"I just told you all you need to know, Gav. Now get moving. That's an order."

"I'm retired. Remember?"

"What difference does that make?" Raft was plainly irritated now, unusual for him. "There's only one way down. Now go ahead and start dismantling."

"Tell me." Gav paused. "Whose idea is this?"

"I have to take the responsibility." There was an edge to the commander's voice. "We knew we were running short, but . . ."

"I don't care how it happened." Gav had to keep himself from shouting. "Who shut the engines down just now?"

Now the pause was on the other end.

"I did." Leif sounded guarded.

"And the chain of command agrees?"

The silence was answer enough.

"So the big boys want me to finish the job up here," Gav continued. "And getting back is secondary. Is that it?"

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"It's not like it sounds, Gav. It was never meant . . ."

"You know what, Leif?" Gav overrode the commander, his tone harsh. "I think they're right. I came up here to do a job, and I'd be here even if I knew I'd never come home again. That's what galls me, Leif. I thought more of you than that. Why didn't somebody give me the choice? Why didn't you tell me? Am I listed as unstable in the files or something?"

"Come on, Gav. I wanted to tell you. It wasn't my . . ."

"Who stopped you? Nobody's stopping you now. Who stopped you then?"

"It's not like that . . ."

"Dammit, that's enough. This is the wrong time to argue about it." Gav was disgusted. "Every second we're falling some godawful number of feet. Start the engines again."

"Gav, I already gave the order. They're stopped. Now be reasonable and come on down."

"Didn't you hear me?" Gav heard the edge in his voice and fought to stay under control. "I'm not coming down until the job is done. Now if I have to go out and punch a hole in the side of the fuel tank just to push us past the point of no return, then that's exactly what I'm going to do. Start the goddamned engines!"

There was no reply from the other end, but after a bit the engines rumbled into life. Gav sat back and thought.

By the time the silence returned Gav knew pretty well where he stood, even though he was still missing a few pieces. He was deciding how to begin when they called him.

"*Atlantis*, this is Houston."

"I copy, Houston. Mission accomplished?"

"Yes, sir. You did a fine job. The world owes you."

"So why don't I hear any cheering?"

He felt bad as soon as he said it.

"Sorry. I shouldn't have said that. Where's Leif?"

"He, uh, he doesn't usually man this station."

"Right." Smartass! Well he'd worry about that later. "Let's talk about fuel."

"Yes, sir."

"I know you've already thought of everything I have, plus a few, so I won't run through them all, but answer me one question. How long would it take to get another unmanned shuttle up here?"

"Thirty days, working twenty-four hours and standing on each other's feet."

"And another manned one?"

"Eighteen to twenty."

Gav sighed. "And either way the radiation would get me."

"Afraid so, sir."

"And if I can get the *Christa McAuliffe* free?"

"Still no go."

"I figured. I just had to ask." He went over everything he'd thought while the motors burned the fuel that should have been taking him home. He'd checked off some points he wanted to make. Somehow they didn't sound as dramatic now. What the hell. "I've got a few things to say. Am I coming through clear?"

"Yes, sir." Gav wondered if this guy was any older than the marine who'd pulled him from that bar. He must be

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if he was in mission control, but he sure seemed young. Everyone did.

"Okay, here goes." *This is your moment in the sun, Gav, in every sense.* "You all know why I'm here. Or at least you know the immediate reasons. I'm going to tell you a more important reason I'm stuck up here.

"Before I do though, I want to clarify something else. Under the circumstances, from where we were a week ago, I wouldn't have it any other way. The glory of the space program is that it's a new frontier, but more than most earlier thresholds this one's an untapped supply of knowledge. That's why we can perform miracles in a suitcase up here that are impossible anywhere on the surface of the Earth. And that's why I applaud the decision to sacrifice one human being's life so that hundreds of thousands will live. And I'm proud that I was the one chosen.

"But the real reason such a sacrifice is required is that this is an unmanned facility. Nothing automatic is foolproof. If people were up here, they might have fixed the problem right away. You might never have heard a thing about it. If people were here there would be shielding and food and water and shelter, and I could wait until the next shuttle came by and simply hitch a ride home. If people were up here, we could do so many more medical and scientific projects that untold lives would be saved.

"Because we're afraid that a handful of people might die in takeoffs and landings and accidents in space, we're letting so many more suffer on Earth. That's not right. If what I've done means anything, let it show that we need to start sending humans up here to claim our destiny in space before we destroy ourselves on Earth."

He paused to collect himself. After a few seconds he realized it was the first time he'd ever heard the radio completely clear. It didn't last long. Starting with a few quiet comments it grew to enthusiastic calls and whistles and applause. They were all behind him, and his eyes grew moist. It was the first time he'd felt like crying in years. Must be getting old.

Now for the rest. "Houston, this is *Atlantis*."

"Go ahead, sir. That was wonderful."

"Crap." Gav smiled in satisfaction. "Can you get me a tight beam to Leif Raft?"

"Excuse me, sir?"

"I'd like to have a private conversation with Mr. Raft. I know it can be done."

"I'll check sir. Please hold on."

"I'm not going anywhere."

He used the time to check status of the shuttle, and to see if there was anything he could jettison. He was trying to figure how to remove the landing gear when the radio came back to life. There was almost no static or background noise.

"*Atlantis* this is Leif Ericsson Raft in Houston. Hello, Gavin. We've got a tight beam set up. No one but us. I guess I deserve whatever you've got to say."

"No, Leif, you were the only one who wanted to bail me out. I was out of line taking it out on you."

"What? Gav, if I were you I'd feel

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tricked and betrayed and ready to take it out on every sunuvabitch down here."

"You know what?" Gav found himself smiling. "That doesn't matter any more. Sending me up here was right. Not telling me about it was wrong, but I know the way some of the brass think, and that all seems so distant now. Even being up here, the one thing I've worked for all my life, that doesn't matter either."

"What does matter, Gav? Tell me about it."

"Hey, don't use that tone. These aren't the maunderings of someone who's over the edge. I'm trying to tell you something. What matters to me now, what matters most in the whole world, is to come home. I know I can't do that, but it seems so lonely to die out here in space. Especially if I have to just sit and wait. I was never any good at that. I'm coming home, Leif."

"You'll never make it, Gav. That's crazy. Wait a little longer. Maybe we'll work something out."

"You know better than that. If there was an answer, you'd have it by now." Gav laughed, and wondered if he sounded unhinged. "You're not going to find anything, and sitting here would make me feel terrible. At least if I try I figure maybe there's a chance. Or a miracle."

"Give us a few days. Who knows what we can find?"

"No. I just wanted to thank you for having the guts to try to bring me down when you knew it would end your career. I hope you do okay, Leif. You're a fine man, and you deserve the best."

"Wait, Gav, don't do this! We can at least tell you how to lighten the shuttle so . . ."

"No, Leif. I'm signing off now. Thanks for what you did."

"But, Gav . . ."

It was with a very satisfying click that he turned off the real world.

There was supposed to be a lid on the whole thing, but ABC picked it up somehow. Peter Jennings came on at 2:30 in the afternoon, EST.

"We have uncovered a news story that is so startling that we're going to waive our usual procedures and broadcast a special without being able to confirm the complete accuracy of it.

"An extremely reliable source has informed us that there was some trouble at the space station *Freedom*, and a secret mission was launched to correct the problem. That mission involved sending a manned shuttle to the *Freedom*. We don't know what type of trouble it was but speculation is high that it involved the antitoxin development system and the astronaut may have been contaminated in the process. In any event, there was a foul-up, and he doesn't have enough fuel to return.

"We have been unable to establish radio contact with the shuttle, but we have an exclusive hookup with Doctor Frederick Benjamin in the NASA Observatory on Maui. Doctor Benjamin, can you hear me?"

The face of a middle-aged man now filled the screen. He might have been a plumber. "Yes. Go ahead."

"Would you tell us what you know about this?"

"Know? I know only what you have told me. If he is trying to save fuel, he will use a long elliptical orbit. Our com-

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puter is calculating the possibilities and trying to lock in on him."

They managed to discuss how little they knew for fifteen minutes without losing a viewer. A beep in the background made Dr. Benjamin look up hopefully and he hurried off to investigate.

He was excited when he came back. "We have it! Come and see!"

ABC had rigged a minicam to a 35 mm camera port on the big telescope and were able to transmit live photographs of the action. There was a lot of speculation but little else as the dark spot on the screen took shape and became a shuttle with an orange spot on its nose. Soon the flame spread to her wings, the jets firing fitfully to slow her down, keeping the flame partially contained. One of the motors sputtered, and the *Atlantis* seemed to pick up speed at an alarming rate. The orange crawled backward outlining more and more of the surface until nothing was visible but a ball of orange light.

Then it went out.

The Florida morning was clear. Not as perfect as some, but excellent for launching the first in the new line of manned orbiters. After the ABC story got out there was no stopping the press. Details surfaced day by day, more confusing with each development. Then a tape of Gav's final speech was discovered and the public reaction was overwhelming. Congress hastily approved new measures introducing strict controls but renewing the manned space exploration program.

The largest crowds ever collected at the Cape were here today, and somewhere in them a fifteen-year-old watched in awe as the countdown reached its end, the engine roared, the flames billowed, and the *Gavin Murrow* lifted off. ■

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the reference library

By Tom Easton

Little Heroes, Norman Spinrad, Bantam, $18.95, 496 pp.
The Dark Lady: A Romance of the Far Future, Mike Resnick, TOR, $?, ? pp.
Firebird, Kathleen Moore Tyers, Bantam, $3.50, 272 pp.
Circuit Breaker, Melinda M. Snodgrass, Berkley, $2.95, 272 pp.
Drowntide, Sydney J. Van Scyoc, Berkley, $2.95, 224 pp.
On the Rim of the Mandala, Paul Cook, Bantam, $3.95, 256 pp.
Annals of the Heechee, Frederik Pohl, Ballantine/Del Rey, $16.95, 339 pp.

He still carries a torch for the sixties and its brand of freedom-flashin' rock and roll. He loves language games, bouncing words off his keyboard, his readers, the walls, and sometimes scoring plenty points with constructions such as "plushy tushies" for the upper crust of a future U.S.A. wracked by technological unemployment, financial crisis, and poverty. He loves head games so much that he can imagine a gigantic musical conglomerate—Muzik, Inc.—that, in its everlasting pursuit of the bottom line, can propose a computer-simulated rock star to whom it need pay no royalties.

You thought maybe I meant Harlan Ellison? Baby, Harlan is one mean and angry fellow, but for sheer cynicism he can't hold a candle to Norman Spinrad, and Norman proves it anew with his latest opus, **Little Heroes**.

Abandoning his realm of void captains and children of fortune, at least temporarily, Spinrad gives us Muzik this time out. It has enjoyed moderate success with AP (Artificial Personality) rock stars, but now it wants one that will ship gold. It therefore engages as producer Gloriana O'Toole, the Crazy Old Lady of Rock and Roll, who sang backup and warmup and second string in the glory days, who still knows what rock and roll was really all about, and

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who itches to show the pinheads upstairs what rock and roll can really do. It gives her computer nerd Bobby Rubin and VoxBox (music synthesizer) mistress Sally Genaro, Sally from the Valley, the Pimple, fat and resentful and panting for Bobby's wimpy bod. It throws in cash, buckets of designer dust (dope), and parties galore.

Meanwhile, a continent away in Manhattan, we see the other end of the social scale—the scum and slime of the streets, represented by Paco Monaco as he discovers the Zap, a device that cross-connects his dream centers to his consciousness and frees his self by letting him tap the more vigorous reality of his musical hero, Mucho Muchacho, ironically a Muzikal AP. There is Karen Gold, daughter of the suburbs, groomed for prosperity as a computer programmer, eking out life on the borders of Manhattan's glamor, sharing an apartment with two others, losing her job to a chip, and sliding into the dreaded, slimy streets. And then she meets the Reality Liberation Front, a coterie of computer wizards who have turned their talents to writing bedbug programs to disconnect people from the IRS or the utilities, or to put people on pension lists, or otherwise to undermine the official reality, and the economy, of government and business.

Against all odds, Gloriana, Bobby, and Sally invent Red Jack and give him a song and dance that meshes with the RLF and the Zap, soon known instead as the Jack. Their AP, the voice of chaos, of freedom, is wildly popular, feeding on and feeding Zap and bedbugs. Muzik wants more, and gets it, but then the bedbugs bring it lawsuits galore. Knuckling to the pressure, it demands a new gold-shipping AP that will counter the anarchic message of Red Jack, and it gets Cyborg Sally, a leather fetishist's wet-dream, to enslave the customers to their gonads instead of their yens for freedom.

If that were all, *Little Heroes* would be a fairly ordinary book. But consider Sally's yen for Bobby, and his unremitting rejection of her pimply, needy bod, so consistent with her past. Is it any wonder that she *becomes* Cyborg Sally and decamps in search of the adulation she *knows* is her due? Consider Gloriana, than whom no one can boogie better. Consider the meeting of Paco/Mucho and Karen, Paco's services to the RLF, the simple fact that when Sally decamps, she goes to Manhattan, meets Paco herself, and gains the worshipers she craves. Consider that when Muzik wants her back, it sends Bobby, and then Gloriana, after her. All the threads come together in the Big Apple, and if the terrorist takeover of the ultimate disco, the American Dream, fizzles, if there are no big heroes for the tale, well, that is the point of the title: *Little* heroes, ordinary people taking some control of their own lives, escaping from the chains of corporate and bureaucratic convention, finding happiness, at least for awhile.

Spinrad's theme is a very sixtyish thing, and one that sometimes seems forgotten, and hence worth reviving at all costs in the eighties. It is the battle of individuality against conformity. The voice of the former is that of Red Jack, its emblem the Zap, its expositors Gloriana and the RLF. The voice of the latter is Cyborg Sally—"On your knees, peon!"—its emblem that ultimate disco, the American Dream, its expositors the pinheads who run Muzik, Inc.

I can probably sum this review up in no better way than to say that Spinrad is trying hard to become the Crazy Old Man of Science Fiction. And, brother, can he boogie! *Little Heroes* is a mag-

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nificent book, and I recommend it highly.

However, you *do* deserve a warning. Paco Monaco's use of Spanish street slang in his introductory scenes is enough to try the patience of the Gentlest Reader; Spinrad has a point here, but he could have made it just as well by reining in Paco's tongue, as he indeed does a little later. There is sex, so pervasive and sometimes so bizarre that you may not want to leave this book in reach of your younger children. There is profanity that *you* may find offensive. There is the singles scene, which so absurdly monopolizes the story that we see not a single married couple, nor children, and every bar and disco is a "meatrack."

Granted, every bit of sex and profanity fits the tale and its characters. The meatracks are an entirely apt emblem for a world in which people exploit each other in the absence of the gentler, nobler sentiments. And "focus" may be a better term than "tunnel vision" for what Spinrad is doing when he omits the married world. But I do find the book consistent with much of Spinrad's previous work: as usual, he has some trouble controlling his excesses.

With **The Dark Lady**, Mike Resnick tries a slightly different approach to his favorite subject matter. Usually, his protagonists are human, drawn somewhat larger than life. Often, they have a distinctly carnivorous streak, and their tales run with the red blood of the American Frontier. This time, his viewpoint character is a candy-striped alien of herbivore stock, a herd creature, an innocent abroad in a world of carnivores.

Dubbed Leonardo for his artistic pretensions, the young alien has been sent by his people, the Bjornn, for training to an art gallery on Far London. An expert in the art of the Albion Cluster, he is asked to appraise a painting of a sad-eyed lady, robed in black, at an auction. When the painting brings many times his estimate of its value, the tale is off and running. The buyer collects portraits of the Dark Lady, and he has items from all over the galaxy and from many centuries. And when he learns that Leonardo knows of two more portraits, he quickly engages the youth's services as a sleuth, despite his hatred for aliens of any and all stripes.

Aided by hints from the underbidder at the auction, one Reuben Venzia, Leonardo soon learns that the Dark Lady has been portrayed many times, usually by amateurs, always—apparently—from life, and over a span of millennia, dating back to well before Man left his home world. Who is she? *What* is she? The mystery comes to obsess Leonardo, just as it does Venzia, when, banned from his people because of the odor of scandal he has acquired by associating with the art thief Valentine Heath, he actually meets the Dark Lady. He learns that she has been called a Goddess of Death in many cultures, that it is her lovers who paint her, and that her lovers are men—and Men only—who habitually risk their lives without thought of profit. He builds a pattern, guesses who her next lover will be, and he is off, with Heath, to ask her for the answers.

Who is she? Mike does not really say, though he gives us clues. Her lovers pursue an ideal of commitment and risk, and her favorite may be the one whose defiance of death is for the sake of art, not adventure or thrills or even love. She is, perhaps, the ultimate muse, the ages themselves, for the sake of whose acceptance artists risk their livelihoods and lives.

Is she truly for Man only? Toward

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the end of *The Dark Lady*, Mike allows the reader to think that she has become ready to broaden her horizons beyond the merely human, perhaps because the human species is on the verge of outgrowing anthropocentrism.

As usual, Mike draws his characters boldly but simply. They are caricatures. Venzia is driven by a consuming desire to know what awaits him. Malcolm Abercrombie, the collector, is a one-dimensional SOB, a plantation squire reincarnated to sneer at robots and aliens. Heath is a scion of wealth whose parents squandered his inheritance, forcing him to thievery in order to maintain his standard of living; he is a Raffles who owes a touch or two to Wodehouse. Leonardo has an intriguing culture behind him—Mike says he modeled it on the herd behavior of African elephants—and it drives his concerns, but he is mostly a pose, a screen for the author's observations of the Dark Lady.

Characterization may not be Mike's strong suit. Nor is action, for he has a tendency to tell his tales almost entirely with dialogue, and *The Dark Lady* is no exception. We read him for the deftness of his caricatures, as we read the comics in the daily paper, and for the effectiveness of his minimalist approach to description—no Vance he. Most of all, we read him for his genius at translating abstraction into moving, effective story without resorting to long lectures that demean the reader's intelligence. I wish more writers could do the same.

Kathleen Moore Tyers is a Californian who moved to Montana in search of Tolkienesque wilderness, and found it. She is also a musician who puts her music into her writing, as subtitles for the chapters and as an important aspect of one of the more charming heroines of the year, the Lady Firebird, the wasteling daughter of the royal family of Naetai.

The novel is **Firebird**. A wasteling is a surplus heir, born as insurance against the death of an elder sibling but doomed to execution, suicide, or nobly heroic sacrifice before any conflicts between the heirs can possibly arise. It's a logical cultural institution, but it does represent a waste, especially when the wasteling in question is a beautiful, talented musician and jet jockey whom the people love far more than her nasty, plotting sister, Phoena.

Firebird gets her chance for heroic sacrifice when she embarks on the invasion of a distant world, in a war plotted by Phoena. Unfortunately, that distant world is under the protection of the powerful Federacy, and the invasion is stopped cold. Firebird is captured. When she takes poison, as is her duty, she is revived and interrogated by Brennen Caldwell, handsome, telepathic, and as alien in the Federacy, in his way, as Firebird on Naetai.

The rest of the tale, though full of complications, is inevitable, for Firebird and Brennen are fated for each other. But before the final, ecstatic clinch-and-fade, they must defeat the evil sister and all her plots, including her efforts to waste the wasteling. To boot, they must overcome two worlds of cultural difference, and Firebird must dare the soul-to-soul commitment demanded of anyone who would love a telepath.

Tyers has a nice touch with the romance. She also recognizes in Firebird that women too can be heroes of action. Unfortunately, she shows signs of contamination by more standard romances—Firebird never actually swoons, but she does display some tendency toward incapacitation at crucial moments. Or perhaps I am being unfair—after all,

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plenty of male heroes of male writers also get bludgeoned, wounded, poisoned, etc., at crucial moments, but come back to win the day. And in fact, Brennen is right there beside Firebird, at least once even in helplessness.

The word is that by the time you read this, the Berkley book label will be no more. According to *Locus*, it will be retired in favor of Ace, whose "identity proved stronger in sf," and all Berkley reissues will bear the Ace label. But don't let that stop you from finding and enjoying any "Berkley" book I tell you about. It's still the same publisher, same title, same author, and the same $2.95 or $3.95 or . . . (Like me, you are probably too young to remember when that was a hardcover price. But you've seen the old pricetags in the second-hand bookstores, haven't you?)

Will you find Melinda Snodgrass's **Circuit Breaker**? Will you enjoy it if you do? That depends. I found it a disappointing sequel to her excellent and different *Circuit*, which introduced a federal judge as hero and constitutional law as the source of the plot conflict. This one brings Cabot Huntington and his clerk/partner/lover Jennifer back, riding the Fifteenth Circuit out to Mars, where the colonists have found a wealth of diamonds and wish to sell them on Earth to fund their terraforming efforts. But terrestrial industry fears disruption, and the new Administration mounts a harassing attack on the colonists. Huntington must stave off the heavy hands of the entrenched bureaucrats in the name of justice and law and save the colonists. In the process, he also strengthens the identity of the off-Earth "System" and gives new meaning to the phrase "working within the system."

This time, I found the plot thin, petty, and unlikely. The diamonds were too weak a monkey wrench, the ecofreak activists too stereotyped, the Administration conniver too much a female Snidely Snavely, and the femme fatale impossibly effective. And Huntington was much too much the mid-life chump, and he and Jennifer spent far too much time feeling hurt.

I am confident that Ms. Snodgrass has in her another book as original as *Circuit*. I wish she had written it. *Circuit Breaker* does have its points—action, sex, and the joy of watching bureaucrats get stuffed—but overall, I think we should credit the book to seriesitis.

I enjoyed Sydney J. Van Scyoc's latest, **Downtide**, much more, though still less than I had expected on the strength of her past work. The problem was largely the obsessively self-conscious dithering of the main character, Keiris, the young son of Queen Amelyor. Yet that same dithering is what drives the plot, and it is a common affliction of adolescents. It may thus make this book more suitable for young adults than for old ones.

Keiris and Amelyor are royal because their line carries the talent for talking to the sea mams and gathering the information on weather and beasts that alone lets the fisherfolk whose efforts support civilization on the narrow land of Neth survive their labors. Yet the talent is dying out. Of Amelyor's several daughters, only one had the gift, and now she is lost at sea. Keiris, who fears the sea, must go in search of his long-lost twin sister, spirited away at their birth by his mysterious—and also missing—father.

It is quickly apparent that Keiris has the gift himself. His "voice" is stronger than his mother's, or his dead sister's.

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But he denies it. It is of the sea, and it threatens him.

And then he finds his father and his father's people, a people of the sea, long thought vanished in the mists of history. He learns that his species and the mams came to their watery world millennia ago, fleeing a world in the throes of ecodeath, hybridized with the indigenes and gained the "voice" talent, and became as much a part of this world as if they had indeed evolved here. At least in part—the landlings deny their watery heritage. Keiris's father's folk do not, and they retain much more of the gift of voice.

The drift is plain: This is a novel of maturation, of coming to terms with heritage and talent and responsibility, and it is in many ways a very satisfying novel of the kind, just as we are used to seeing from Van Scyoc. But Keiris does spend an appalling amount of time obsessing along the lines of "Should I do . . . ? I can't . . . I must . . ." when most people—I think—tend to do their obsessing after the fact, wondering "Should I have done . . . ? Was I right? Was I wrong?"

You say you don't agree with me there? Then you'll surely love the book. You do agree? Then I expect you too will have trouble identifying with Keiris and grow impatient with his melodramatic posturings.

Paul Cook did some nicely ambitious work, based on some nicely original ideas, with his first two Bantam novels, *Duende Meadow* and *Halo*. Happy readers made him a success. And now, perhaps because his editor has been after him, crying, "Do it again! C'mon!" we have a third novel.

Alas, **On the Rim of the Mandala** is such a disappointment that I could not possibly suggest that you spend hard-cover money on it. Fortunately, it's a paperback. It has a nice idea or two, too, and if they are not enough to lift it out of the category of stock adventure . . . well, what do you expect these days for $3.95?

The Mandala is the center of a space-going civilization. Centuries before, humans had discovered a strange form of energy emanating from a point light-years away and found that it could be used to power faster-than-light travel. Exploration soon revealed that the energy's point of origin was a strange artifact, the Hub, from which fanned out several beams of energy, each one defining a spoke of a cosmic wheel, the Mandala. And the wheel turns, the spokes sweep through space, and in due time Earth is lost to the slower-than-light realm between the spokes. Yet human civilization remains among the Mandala's stars, and this is where the story is set.

Mandala begins as Lou Colleran, immortal Three Spoke Regulator for the Mandala Authority (i.e., cop), returns to duty from vacation. A ravening monster bursts from the ship's cargo hold and devours all in sight. Lou blasts it into oblivion with his "Langstrom clasher"/disintegrator and promptly earns a starring position on the team assigned to track the beast's origin. The mission gains considerable urgency when more of the beasts, each different but all clearly of the same kind, appear. A war is brewing, fought with the nastiest of weapons, and it is up to Lou Colleran and the Mandala Authority to stop it.

As you might expect, they do. The clues lead inexorably in one direction. Initial hints that the beasts are genetically engineered constructs are confirmed. And finally . . .

Enough. It's stock adventure, yes, and it reminds me of all the Galactic

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Patrol yarns I thought SF had outgrown years ago, and the science is sometimes awfully sloppy (as when Cook credits the smell of rotten eggs to methane instead of hydrogen sulfide). But I've got to admit that I enjoyed large chunks of it. Cook has a gift for keeping things moving despite an occasional stinky stopper.

Some years back, Frederik Pohl astounded us all with *Gateway*. And then there was *Beyond the Blue Event Horizon*, and then *Heechee Rendezvous*. Bit by bit, told through the eyes of ace neurotic Robinette Broadhead, he revealed a future in which humanity has found in the Solar System the artifactual remnants of a long-gone interstellar civilization, that of the Heechee. The artifacts include ships that, when appropriately stimulated, take off for distant stars but cannot be navigated. The prospectors we met in *Gateway* rode the ships to their preset destinations. Some never came back. Some came back dead. And some, like Broadhead, brought back such prizes that they were rich. But none ever solved the mystery of the Heechee.

Until *Horizon* and *Rendezvous*. Then Pohl told us that the Heechee were hiding within the black hole at the center of our galaxy, trying to escape the notice of the dread Assassins, strange energy beings that destroyed civilizations that caught their attention. The reason? Apparently, they had engineered the universe to close upon itself and recreate the Big Bang, and thus to create a new universe more to their liking. And they didn't want any upstart newcomers interfering with their plans.

Here we have the Heechee, hiding in their hole. And here is humanity, ramming around the galaxy as if determined to call all possible attention to itself. At long last, the Heechee emerge, a finger to their lips, telling us to cool it, please! To which the bold, testosterone-brained generals say, G'wan! *We* ain't chicken!

Or is this the attitude only of meatheads? Broadhead dies and is transcribed—or vastened—into the gigabit space within a computer. He has left meat behind, and he too says G'wan. So now what?

Now we have Pohl's latest, **The Annals of the Heechee**. The viewpoint character is still Broadhead, to whose neuroses vastening has added an immense capacity for parallel streams of consciousness. This seems a fairly likely consequence, but unfortunately, Pohl tries a bit too hard to show us what it would mean in practice. He flits around his plot, from time to time telling us self-consciously that he knows this seems as cute as kittens, but . . . And the combination of neuroses and flibberty-gibbeting makes *Annals* just a mite hard to follow at times.

But only at times. Be patient. Give Pohl a chance, and he will tell you how the military meatheads interrupt the grandest party of all time, how the Assassins finally emerge from their kugelblitz outside the galaxy, how two of the nastiest possible villains seize three of the nicest possible kids, how Broadhead saves the day once more, how the villains turn out not to be so nasty after all, and of how Pohl implicitly reiterates an ancient quote from Walt Kelly's Pogo.

Does that look like I have just told you too much? 'Tain't so. Not that you need my teaser—Pohl teased you enough with the first three volumes in the series—but I deliberately phrased my "revelations" to mislead you! If you want to know the whole story, read it.

* * *

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ANADEMS

Introducing a new feature: **Anadems!** (The word means "garland." Got a better one? Then tell me!) It is my way of recognizing (but not reviewing) *Analog*'s own in this column, despite the official policy of not covering things that have appeared before in these pages, or that have been written by the magazine's staff or by this columnist. I will also use this feature from time to time to mention reissues of books I have reviewed in the past, and which I think still warrant your attention.

So what have I got for you this month? For hardbounds, how about Gordon Dickson's **Way of the Pilgrim** (Ace, $16.95, 352 pp.), concerning the struggle against the Aalaag tyrant? Larry Niven's **Smoke Ring** (Del Rey, $16.95) is being advertised as I write this. So is Donald Kingsbury's **The Moon Goddess and the Son** (Baen, $15.95, 409 pp.), an expanded version of the one you saw here.

Paperback reissues? Andrew Greeley's **God Game** is out from TOR, as are Roger Zelazny's **Unicorn Variations** from Avon, Arthur C. Clarke's **Songs of Distant Earth** from Del Rey, Brian Aldiss' **Helliconia Winter** from Ace, and Timothy Zahn's **Cascade Point** from Baen. ■

ON GAMING

(continued from page 103)

lence and conflict.

As do, the writer admitted, many of the science fiction stories in *Analog*.

And for good reason, I'd suggest. As Will Shakespeare—who was known to have littered the stage with dead bodies—knew, conflict is dramatic. In anticipation and resolution, it makes a situation powerful, fraught with importance.

Which is why computer games about balancing the checkbook and going shopping aren't readily available.

But the real point here, certainly well taken in regard to the *Photon/Lazer Tag* phenomenon, is the "mindlessness" of the violence. If the conflict is divorced from meaning, from its reality, it becomes empty, and I'd hazard a guess that it just ain't any good for the human soul.

It's the difference between the horrible, almost overwhelming violence in George Romero's film *Day of the Dead*—harnessed to a remarkably redemptive message—and the host of horror and "action" films that feature splatter like so much human flavoring. But whether leavened by humor or some message more profound than "kill the bastards," conflict and violence are valid and viable themes for art—whether it's *In Cold Blood* or *Star Wars*. ■

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brass tacks

Dear Stan,

RIGHT ON, RIGHT ON, RIGHT ON!

You have definitely hit on something solid, tangible, and worth a serious investigation! You took a somewhat limited view of the subject, but after all, an editorial invites different points of view, even if they don't necessarily take an opposing viewpoint.

I refer to "Brain Language" (March 1987) . . . hoo, boy, did you ever hit some nails on the head. Points in support:

1. I don't recall which magazine it was, but *Omni* comes to mind, wherein I read a report discussing a peculiarity observed in the alcoholism research community. They discovered that people under the influence of alcohol (and, presumably, other consciousness —altering substances) could recall events, facts, and other items when under the same degree of influence as when those facts were introduced to them, BETTER than they could if quizzed upon them in a sober condition later. While I don't pretend to be an expert on the physiological implications of this phenomenon, the immediate implications seem to support the theory of a personal brain language. If a person does some thought processing under the influence of a mind-altering substance, the processing language seems to be altered as well, and in the unaltered state of mind, even the person whose thoughts are involved cannot deal as effectively with the data in question as they could under the influence (or condition) in which they were initially processed. Assuming, of course, that the observations are correct in the alcohol-memory study.

2. To further support your theory, an interesting case history came to mind regarding a young man named "Percy." He stood in front of an audience and blithely rattled off the days of the week

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that particular dates in particular years fell upon. The questioners asked for days with which they were familiar, such as one fellow's daughter's birthday, and he was found to be absolutely correct. But when he was asked how he did it, what his method was, he turned to his sponsor and asked, "What does that word mean, 'method,' Doctor?" Percy was an idiot savant . . . a peculiar adept with a phenomenal and irrational talent, but whose personal brain language does not extend to include the type of thought processes necessary for "normal" social interaction.

It was interesting to note that Charles Sheffield's "Trader's Cross" was to feature such a person later in the issue.

3. The same week the issue arrived here, National Public Radio's "All Things Considered" was discussing the peculiar case of a pair of twins in Great Britain who had, since birth, communicated in a language of their own devising, to the virtual exclusion of all other forms of communication or interaction with other human beings. . . . to the extent that when they mutually decided to commit homicide, as long as their own thought patterns seemed to agree, they proceeded with no regard for society's reaction to the act of murder. Their only regrets sprang from the fact that the judiciary decided to permanently split the pair up.

And perhaps most intimately of all,

4. Your editorial seemed to limit itself largely to the community of writers and other people who deal almost exclusively in words. Consider, if you will, the "translation" activities involved with those of us who don't think in words at all, but whose brain-language compiles itself in visual images. In this respect alone, your editorial spoke volumes to me.

Your description of translating one language into another, and having to discard the thought processes involved in speaking English in order to correctly verbalize your thoughts in another form of expression, is one with which I believe you will find each and every one of your artists is intimately familiar. In fact, were the truth to be known, the same kind of non-English thought is doubtless required in every specialized form of communication or thought. John Cramer is a perfect example of someone who constantly shows me that he thinks in a language other than English . . . he just happens to be one of those rare individuals who can translate physics to English effectively. Several mathematics teachers in my dim, dark past were not so equipped, and were frequently noted to answer direct questions with statements like, "Can't you *SEE?* Isn't it *OBVIOUS?*"

No, it wasn't always obvious. But interestingly, while failing miserably in an algebra-II/trigonometry course, I was taking a physics-IV class from another instructor who verbalized the nature of the problem, and helped his students visualize the solution. We were using identical formulae, precisely the same mathematical expressions . . . yet while I had to withdraw from the algebra/trig class to save my grade point average, I was ace-ing the physics class. Go figure. (No pun intended.)

See to it that a bunch of artists get their hands on "Brain Language" and solicit responses. I believe you will find a great deal of consensus.

BILL WARREN

Greetings,

This is a call to whoever may know the whereabouts of any current research or activity in LOGLAN.

Loglan is an artificial HUMAN language developed by James Cooke Brown.

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It has a grammar based on the laws of formal logic, and a vocabulary derived algorithmically from the corresponding words in the eight largest natural languages. The rules of spelling and pronunciation are designed so that any given string of spoken Loglan syllables can be parsed into words in only one way; this makes the language uniquely suited for machine transcription. The overall goal was to design a language with minimum ambiguity, that could express the full range of human thought.

It strikes me that with proper software, current personal computers could serve as Loglan tutors; besides its potential as an international auxiliary tongue, Loglan could become the *Lingua Franca* of intelligent machines. It might also serve as an intermediate stage in machine translation between the eight largest natural languages.

James Cooke Brown originally hoped to test the theories of linguistic philosopher Benjamin Lee Whorf. If people could become fluent enough in Loglan to think in it, the clarity and efficiency of their thinking should improve. I have not heard if this level was reached; the most recent material I have found is from 1975. Loglan research was always a shoestring affair, largely financed by Brown himself. If the language could be made available to computer hobbyists, much more might be done.

If anyone knows the current status and whereabouts of Loglan research, please write to me at the following address:

JOHN HODGES
P.O. Box 912
Blacksburg, VA. 24060

Dear Dr. Schmidt:

This is in response to an article in the March, 1987 issue by Tom Pace and Dan DeLong. That article, entitled "Cheap But Not Dirty: Proposal for a Spaceplane," presented an alternative to the Shuttle design. The article proposed an industry-supported spaceplane, and had a fair amount of technical analysis demonstrating the technical feasibility of the proposal. Until the same degree of sophistication is applied to the financial analysis, that spaceplane has almost no chance of advancing beyond its current level of development. By the way, my comments below are based on my experience in a different engineering discipline—petroleum engineering. Although many of the details of my business are different from the aerospace business, I would expect the financial framework to be little changed.

There were three main phases proposed: Research and Development, Construction, and Operations. The R&D costs were estimated at $4 billion, including financing. However, it is doubtful whether any of the R&D expenditures could be financed, because of the high degree of risk involved. There are too many things that could go wrong and prevent completion of the spaceplane as a commercial venture. The risks are too great for banks, pension funds or insurance companies. The R&D phase will require the use of "venture capital," at an interest rate of 25% per year or more. The high interest rate is required by venture capitalists to allow their few successful projects to offset the failures. If the $4 billion R&D estimate is correct, the interest charges alone on the R&D funding would be $1 billion per year.

Following the R&D phase, there will be a Construction phase for the eight spaceplanes, at a quoted cost of $4 billion. We will presume that this quote includes construction financing costs, which could add 10% or more otherwise. Ignoring any equity participation

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requirements, if the construction is financed over 15 years at 10%, there will be annual debt service payments of $256 million to cover the Construction.

The Operating cost for the project was estimated at $351 million per year. There are some obvious problems with this estimate: for example, will salaries, including maintenance and clerical staff, really average $130,000 per year per employee? If so, the project will be inundated with resumes of prospective employees. Property taxes were not considered, but could total $40 million per year, based on 1% of value. Income taxes would be another add-on, presuming the project ends up making a profit. And let's not forget that a significant sales force will be required to assure full payloads of 350 flights annually. It would be a shame to have a spaceplane with the percentage of capacity that the airlines have been achieving recently. For the purposes of discussion, let's assume a cash operating cost of $500 million per year before debt service.

For the stated target of 350 flights per year at 15,000 pounds of payload per flight, the annual payload would be 5,250,000 pounds. The cash operating costs would be $95 per pound, with equipment debt service of $100 per pound and R&D venture capital interest charges imputed at $190 per pound. This leads to a cost of $385 per pound for the second stage of the spaceplane, compared to the stated estimate of $134 per pound. The impact of a smaller market than projected, or longer turnaround between flights, could drive the cost per pound up higher than the Shuttle.

I hope this letter provides a flavor of the financial analysis that would have to be done before the project could even begin to get started. A couple of other points should be made. First, $4 billion R&D capital for a single project is just not available in the private sector. To have any chance of being realizable, that number has to drop to no more than a few hundred million dollars. Secondly, the investors have to receive a reasonable return on their investment, or they are better off putting their money into stocks, bonds, real estate, etc., with much less risk. The cute ideas like "How many individuals are out there who would buy $500,000 worth of non-voting stock if it also meant getting an assigned number on the passenger manifest?" will not sell the concept. Such investors will buy stock once it has been demostrated to have a low risk and acceptable return.

In summary, the spaceplane concept may have merit, but it will have to be able to survive rigorous financial scrutiny. As presented in the article, it does not appear to pass the cursory screening analysis of this letter. I enjoyed the article, and hope the authors can succeed in generating more interest in the topic.

DAVE O. COX
3035 Deframe Road
Golden, CO 80401

Coauthor Tom Pace replies . . .

Mr. Cox's letter, nominally questioning the financial estimates in our article, points up something we should have stressed. The Spaceplane, or any similar project, will be dependent on a major boom in space utilization. That such a boom is coming, with space manufacturing, space station activities, increased use of planetary probes, and asteroid belt explorations, seems highly likely. Whether this country does it or not, the Russians and the Japanese will.

But there is not going to be massive utilization of space without the ability to put massive amounts of material into orbit. A very large number of systems to do this are likely to appear: see G.

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Harry Stine's article in the February Analog. The Spaceplane will possibly be one of them; and given a drive to build working installations in space, and the financing required for that effort, the financing for the lift systems will be available.

Specific points:

Four billion dollars for developing the Spaceplane and its carrier modifications was meant to include the cost of financing, and was so stated. We also stated that we felt four billion to be conservative (and we still feel so), but we also looked at eight billion. Including financing.

I somehow doubt that the people Cox has in mind should be called "venture capitalists." Cox is thinking of people who want a sure thing. TRUE "Venture capitalists" interested in a Spaceplane are probably going to be the people who want to use it to pipeline freight up and product down.

I am also reminded of Nevil Shute's comments on "venture financing," specifically conerning British banks, in Slide Rule (a book that should be read by every engineer and every aviation buff); as Shute said, "We couldn't let the rats get at it (their capital) like that." Right on.

I feel Cox similarly overestimates the financing charges required for construction of the Spaceplanes.

With fringe benefits, insurance and other overheads, the salary figure we quote is not too unreasonable, for the near future. I somehow doubt we'll need the huge sales staff he mentions. I think Mr. Cox is telling us why the oil companies have recently had to lay off so very many employees! Thirty years of unrelieved boom-time *can* do that to large companies; fatten them to the point of ridiculousness.

Finally; we used a fleet of eight planes, at 350 flights a year (and 547 flights a year); just for first estimates. If eight work as well as we think they might, there will be quite a few more than that in service, ultimately.

And again; we did *not* discuss a replacement for the Shuttle. We specifically pointed out that we were discussing the need for a supplement to the Shuttle; one of the several supplements that are already badly needed, and will definitly appear as the need for orbiting capacity grows. Not that we don't already have a panic situation, with no present way to get things into orbit, except for the few Deltas the Air Force has!

We mentioned Mr. Heinlein's D.D. Harriman. D.D. Harrimans are the financiers industrial development needs; not people who want to invest in condominium construction, or to loan more billions to Brazil or Mexico. Apply to your local friendly Japanese consortium, one that wants to build a Powersat.

TOM PACE

Dear Dr. Schmidt:

Messrs. Pace and DeLong have proposed a thoughtful method for placing cargo into orbit. As they made clear in their article, and has stressed in similar papers, technology is not the limiting factor in the development of Space, rather the limitations are politics and economics. Let us find a way to surmount those obstacles and innovative people such as Messrs. Pace and DeLong will give us a hundred ways to get into Space.

Let me make a suggestion which may ease some of the nontechnical problems. I own a few shares of McDonnell Douglas stock. I will try to get two resolutions introduced at the next stockholder's meeting. The first would require McDonnell Douglas Corporation to lobby

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for the passage of Commerical Space Incentive Act. The second would require the Corporation to set up a study group to explore ideas such as Messrs. Pace and DeLong's.

Nothing, of course, precludes stockholders in other aerospace firms from doing the same thing. In fact it might be an excellent way to see how good an investment you have made. With the commerical and military aircraft markets drying up, an aerospace company which does not pursue markets in Space will prove as sound an investment as a buggy whip firm.

Stockholders in airlines may also get into the act. I understand that some airlines such as TWA have Space services divisions and would have a legitimate interest in pushing Space development.

Space development advocates have pushed on Congress directly, sometimes with excellent results. But we should use all the tools in the bag. The leverage provided by large corporations could make our dream come true.

DONALD WILKINS

Florisant, MO

Stanley:

I am writing to discuss the science article *Cheap But Not Dirty: Proposal For a Spaceplane* by Messrs. Pace and DeLong in the March 1987 issue. I like their proposal and attitude: that we need a cheap way into space. However, there are several points that they are apparently not aware of that I would like to mention.

They propose to use a Boeing 747 to launch the spaceplane from 39,000 feet and Mach 0.84. First of all, the current 747 carrier aircraft is restricted to about Mach 0.60 with the shuttle on its back, due to the extreme turbulence generated about the horizontal stabilizer by the shuttle (even though the carrier has additional stabilizers to help counteract this turbulence). And this is when the shuttles have a tail cone installed to smooth the airflow. Also, the range of the current carrier is only about 2,500 miles, due to the weight and drag. I can't recall what altitude the Enterprise test shuttle was released from, but I'm sure that it wasn't as high as 39,000 feet. I think that it would be difficult (not impossible, but difficult) to get a 747/spaceplane combination to 39,000 feet and Mach 0.84 because of these considerations.

A second consideration relating to the 747 aircraft is the fuel/gross weight calculations that they put forth. They assume that you can trade off fuel for gross takeoff weight. This is definitely not true. The fuel in transport aircraft is carried in the wing. This means that the wing structure (main wing spar) does not carry the weight of the fuel since the weight of the fuel is carried directly by the wing, and not transferred to the plane's body via the spar (except on the ground, which is a different situation). The main wing spar is, therefore, only strong enough to carry the plane's body and normal cargo. Increasing the cargo weight in such a manner as indicated could well exceed the spar's strength (obviously, there is extra strength there, but you'd probably eat up all your safety factor.) So I think that their design gross weight for the spaceplane is probably much too high, significantly reducing usable payload.

Also, later in the article while discussing reliability and safety, they indicate that they plan to have the spaceplane's main engine start while still on the 747 carrier. If you did this, you would certainly blow the horizontal stabilizer to bits, and lose the craft, just as the Japan Airlines 747 was lost last

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year. So you must release the spaceplane first, reducing the reliability.

It seems to me that you will need two or three carrier aircraft. A 747F costs about $100 million (new), and the modifications for the NASA carrier ran another $100 million, if I recall correctly. I never saw a mention of this $400-$600 million investment.

In addition to this loss of reliability, there is no mention made indicating that the authors know that the Space Shuttle Main Engines (SSME) cannot currently be started except at the pad. There is a spark generator on the pad that is used to ignite the engines. Earlier oxygen/hydrogen second and third stages had the igniters in the interstage unit that ties them to the previous stage. Now we're talking more weight and complexity on the spaceplane. Also, considering the number of aborts due to SSME failure just after startup, I think the reliability is going to suffer. This might be offset by less conservative shutdown limits, due to the non-man rating of the spaceplane.

Just using the SSME for the powerplant is quite risky. The authors indicate, while discussing cost and turnaround time for a spaceplane, assume a four-day turnaround for the spaceplane. No way! The SSME, although designed to last 50 flights before rebuild, in it's current state of development doesn't last more than about 10 flights, and must be completely checked between every flight. I would be surprised if you could get the turnaround down to two weeks under such circumstances, and I think three or four weeks is more likely. In addition, the cost of acquiring new engines every ten flights would steeply raise the costs, since a SSME is not cheap.

In conclusion, although I applaud the authors for their ideas and enthusiasm, I think that many aspects of their design will not stand up well under close scrutiny. I would like to think that I am wrong, but Murphy and my experience at Boeing and as an engineer tell me I am not.

FLOYD ROGERS

Coauthor Dan DeLong replies . . .

Space shuttle ferry flights are typically flown below 15,000 feet for several reasons, one of which is the requirement to keep residual propellants in the unpressurized, unheated orbiter from freezing (Nitrogen tetroxide freezes at 11.8° F). At this low altitude, speed is limited by dynamic pressure on the airframe, and fuel consumption is far higher than it would be at the airplane's design cruising altitude. The drag reducing tailcone on the orbiter increases range and 747 empennage fatigue life, but it is by no means a requirement; the third Enterprise free glide test flight omitted the cone.

The first Enterprise glide test flight reached 28,014 feet before the 747 performed a pushover maneuver to achieve positive separation at 24,100 feet. We assume the 747 can get to higher altitude by using Pratt & Whitney suggested hydrogen afterburners added to the standard JT9 engines. Our proposed separation includes use of the spaceplane auxiliary (not main) engines at 40% thrust to overcome spaceplane drag and allow positive separation without the pushover, and we have been assured by Boeing that this would not

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require further modifications to the airplane's tail.

If the main engine fails to start, the auxiliary engines have sufficient thrust to power the vehicle for several hundred miles before it becomes a glider for a normal landing. Starting the SSME at altitude certainly needs to be demonstrated, but there is no reason to believe that this would be difficult. The RL-10 hydrogen-oxygen engine has never failed to start or restart in flight, and its igniter is nothing more than a sparkplug and a relatively small exciter box. Lighting a LOX/LH$_2$ engine is not difficult unless the injector design allows a poor mixture around the ignitor.

Reader Rogers's concern about our trading fuel for payload is valid. Spar strength calculations include many assumptions, including number of cycles to failure, whether the aircraft is commercial or military, etc. Boeing personnel have assured us that our 20,000 lb. allowance for additional structure is sufficient for this application.

Regarding the comment about 747 costs; we allowed ten times the current 747 price per pound and we feel confident that this will pay for the fleet of 747s.

Overhaul time required for the SSME is not a factor in spaceplane turnaround time, as our assumption is to change engines between each flight, if necessary. Shuttle engines are now overhauled after every flight at a cost of about $2-3 million per engine. We assumed $1 million per flight (20% of the total flight cost!) based on half the burn time and never going above 100% rated thrust. NASA currently has SSME reliability improvement contracts out to both Rocketdyne and Pratt & Whitney, because it is widely recognized that overhaul costs are excessive.

Finally, we would like to point out that Boeing has already proposed a similar vehicle to the U. S. Air Force. There is a color illustration of it in the May 1986 issue of Popular Science *magazine. Our proposal can be thought of as an optimization of this concept for freight hauling rather than for military missions.*

DAN DELONG

Dear Sir:

I am an avid science fiction fan and really enjoy the games and toys that are on the market. I am also a Toledo police officer who wants to advise caution and to ask people to please be responsible when playing with these new laser guns. They are wonderful toys, but in a dark secluded park they can look REAL. My partner and I nearly shot a 16-year-old boy playing with a toy gun. People who are not familiar with guns are nervous at night (particularly due to the large number of gun-related crimes involving 16-24 year olds) when kids run around with weapons. NEVER point it at anybody unless they are familiar with the game. I know this may gall some, but PLEASE notify immediate neighbors or even possibly the local gendarme if you are going to be playing, especially after dark.

DONNA MOMINEE

Elmore, OH ■

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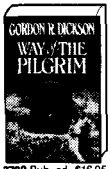

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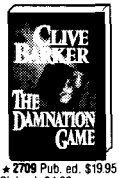

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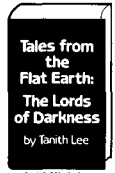

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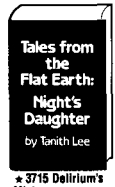

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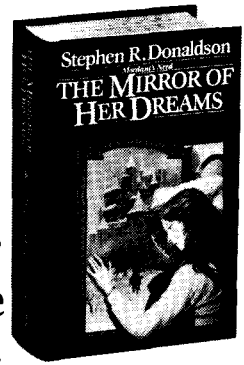

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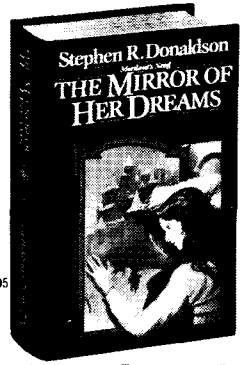

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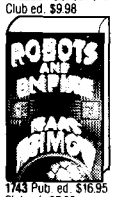

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